



CITY OF APPLETON

Date: June 29, 2026

To: Members of the Board of Health, Safety & Licensing Committee, and Common Council

From: Mayor Jacob A. Woodford

Subject: Resolution 8-R-26 – Excessive Vehicular Noise Data Collection

Resolution 8-R-26 was introduced on June 3, 2026 by Alderperson Smith and referred to the Office of the Mayor for initial review. The resolution was referred to a joint session of the Board of Health and the Safety & Licensing Committee given the presence of overlapping jurisdictional issues.

Per the Common Council handbook, as well as foundational American constitutional principles, the Common Council serves as our Legislative Branch. As such, its purview is establishment of policy/ordinances and appropriations. The Executive Branch, overseen by the Mayor, is responsible for execution of policy and stewardship of the appropriations made by the Common Council. This includes providing management and direction to the City's staff.

As submitted, Resolution 8-R-26 seeks to exercise executive authority by directing staff to conduct specific tasks. While the resolution states that the "Common Council directs the City of Appleton, in consultation with the Appleton Police Department and Health Department" to carry out an exploratory work task, it is reasonable to surmise that in this case, the "City of Appleton" refers to the Mayor and the Executive Branch. This is not in order as drafted and will require amendment should the joint session and Common Council wish to form an action pursuant to the spirit of the resolution.

Rather than simply leave our analysis at this, which is all that is required, I directed staff to review the content of 8-R-26 and to provide context and information. The matter of excessive vehicle noise is real and is of concern to my administration and to the public. We have taken real steps, including enhanced enforcement and design interventions, to make progress on addressing vehicle noise. Additionally, the research contemplated in the resolution is highly technical in nature and, in a number of areas, is beyond the in-house capabilities of our team.

We have included this context in the enclosed documents for your review.

As you will see, the contention that we lack systemic data of any sort on this matter is not grounded in fact. Rather, the public discourse of this problem centers on the demand for more aggressive enforcement. Here, too, we will provide context regarding the statutory and resource limitations of an enforcement-based approach under the current framework. With respect to State Statutes and the justice system, much of that is beyond the scope of municipal control.

On the matter of allocation of law enforcement resources, we have substantially increased enforcement emphasis and will present empirical evidence of that investment. Further enhancement of an enforcement-based approach would require substantial reallocation of law enforcement resources and focus from other APD priorities (for example training; equipment and technology; crime prevention, intervention, and investigation) -or- reallocation from other City of Appleton departmental budgets to add law enforcement capacity for this purpose.

Finally, it is worth noting that all this information has been discussed at length in various formats with the author of the resolution over the last year or more. This includes the aforementioned separation of powers concern. Resolution 8-R-26 was not discussed with staff prior to submission, so there was no opportunity afforded to collaborate with the author on the fundamental structural issues ahead of time.



MEMORANDUM

Date: 6/29/2026

To: City of Appleton Board of Health, Safety & Licensing Committee, & Common Council

From: Charles E Sepers, Jr, PhD, Health Officer

Subject: Response to Resolution #8-R-2026

Purpose

This memorandum responds to Resolution #8-R-26, which directs the City of Appleton to evaluate methods for collecting and analyzing vehicular noise data, with a focus on identifying the frequency of extreme incidents that disrupt the ordinary lives of residents.

This memo evaluates the four methods of noise measurement named in the resolution, 1) fixed monitoring stations, 2) mobile monitoring equipment, 3) citizen reporting agreements, and 4) automated noise-detection technologies. It also addresses the legal, scientific, and practical complexities that govern what any data collection program can actually measure, what it cannot, and how its findings should be honestly interpreted.

This memo draws on several primary sources: the joint Appleton Departments of Health and Police Noise Complaint Enforcement Analysis: 2026 Statistical Brief ("the 2026 Brief"), a memorandum from Assistant City Attorney Darrin Glad regarding Wisconsin traffic law, primary research from residents conducted to inform the Community Health Assessment reports from the City of Appleton and the Tri-County Community Health Coalition, and published research on acoustic measurement methodology and automated vehicular noise enforcement.

Central Finding of This Memo

Before evaluating any data collection method, the City must address a legal constraint that fundamentally limits what acoustic monitoring can achieve. Under Wisconsin state law (§ 349.03), vehicular noise from an unmodified exhaust system is lawful at any decibel level and cannot be regulated by local ordinance. Measuring sound levels alone, without determining whether a vehicle's configuration was lawful or unlawful, does not produce data that is relevant or actionable for the problem this resolution seeks to address. The 2026 Brief already provides a clear picture of the city's noise landscape, making the necessity of a new data collection program questionable. That program would also be cost-prohibitive, representing up to 30% of the Health Department's General Fund Budget, which exceeds what the Department spends on any other single health issue. Additionally, both the Appleton and Tri-County Community Health Assessments identified mental health and access to basic needs as the community's highest health priorities. Given the legal and scientific limitations of acoustic monitoring in the proposed context, its disproportionate cost, and not being a chief health priority identified by the community, the Appleton Department of Public Health cannot recommend adopting Resolution #8-R-2026 in its current form.

Background

The Controlling Legal Constraint

Wisconsin state law establishes the regulatory framework within which Appleton's noise ordinance operates (§ 349.03). That framework has a critical implication for this study: local municipalities do not have authority to regulate vehicular noise that originates from an unmodified exhaust system. Regardless of how loud a vehicle is, if its exhaust system is in its original, unmodified condition, the vehicle is operating lawfully under state law, and no local ordinance citation can be issued on the basis of noise level from the exhaust alone.

In accordance with § 349.03, Appleton's updated 2025 ordinance can and does regulate:

- **Modified exhaust systems** that produce noise beyond original equipment manufacturer (OEM) specifications;
- **Vehicle equipment not in compliance** with applicable state equipment standards; and
- **Willful noise-producing behavior** such as deliberate engine revving or tire squealing.

Why This Matters for Data Collection

The legal violation is not a decibel threshold. It is a mechanical fact about the vehicle. Whether a vehicle's exhaust is modified is a physical characteristic that must be observed or inspected. It cannot be inferred from sound pressure readings, despite its implications for public health.

A sound level sensor measuring 92 dB(A) on a downtown street cannot detect whether that reading came from a legally operating semi-truck, a motorcycle with a modified exhaust, a diesel pickup with an aftermarket muffler delete kit, or a performance car with a factory sport exhaust. All four may produce similar readings. Only one may be a legal violation.

Acoustic data alone does not distinguish lawful noise from unlawful noise. A data collection program that cannot make this distinction will measure the urban acoustic environment in aggregate but will not tell the City how much of the noise burden it has legal authority to address.

Health Prioritization by the Community

In assessing where the issue of elevated urban noise ranks against other health issues, staff reviewed the two Community Health Assessments (CHA) that guide health priorities in our region: the City of Appleton 2025 Community Health Assessment and the 2025 Tri-County Community Health Report produced by the Tri-County Community Health Improvement Coalition (covering Calumet, Outagamie, and Winnebago Counties). Neither report references noise, sound levels, or noise complaints as a health concern, a resident-identified priority, or a data category of any kind.

Instead, both assessments point to a different set of priorities. The Appleton CHA shows that residents rank mental health, housing affordability, childcare costs, food security, and social isolation as their top concerns, with mental health named the single greatest issue facing the community by a wide margin. When residents did raise traffic-related concerns, the focus was on speeding and driver behavior, not on sound. The Tri-County Report reaches a similar conclusion at a regional level, identifying wealth inequality as the leading driver of poor health outcomes, with transportation safety, housing, and access to care as the vital conditions most in need of attention. Given this, any request for capital and staffing dollars tied to noise enforcement should be framed honestly: as a tool that supports adjacent, documented priorities like traffic safety and neighborhood quality of life, not as a response to a need that Appleton residents have identified and expressed, unprompted, in response to a survey instrument regarding public health concerns, or that regional health data have identified. This distinction matters both for public credibility and for making sure limited health dollars follow where the community has said its greatest needs are.

What the Existing Data Tells Us — and What It Cannot

The 2026 Brief provides a rigorous five-year analysis of noise complaint filings and enforcement actions from January through May of each year from 2022 to 2026. Its findings are analytically sound and important for understanding the enforcement landscape.

While complaint data is not a perfect proxy for sound pressure measurements, it offers something noise data cannot: social validity. Social validity is a measure of whether a sound is perceived as acceptable given its context. For example, a commercial lawnmower and a neighbor playing amplified music may produce similar decibel levels, but the music, as a violating behavior, tends to trigger complaints far sooner. People tolerate lawful noise sources more readily, making complaints a more reliable indicator of genuinely disruptive behavior than raw sound measurements alone.

Additionally, real-time enforcement provides officers the opportunity to educate rather than penalize motorists. This initial approach is in alignment with the principles for community policing. For example, a damaged exhaust system may produce noise similar to one that has been intentionally modified. In this scenario, the circumstances behind the violation matter significantly. An officer can distinguish between a motorist who cannot afford repairs and one who has willfully modified their vehicle and respond with appropriate discretion. This kind of contextual judgment represents a form of social validity that sound pressure data alone cannot capture.

A. What the 2026 Brief Establishes

- Noise complaint volume has been stable for the last five years, ranging from 182 to 216 filings per year during the January–May window, with no meaningful trend.
- Enforcement actions in 2026 reached 306 total — 43 percent above the prior four-year average of 214. This is a statistically confirmed increase driven by a change in officer behavior, not a change in complaint volume.
- The 2026 enforcement rate of 1.52 actions per complaint is 44 percent above the prior four-year average, confirming the increase is behavioral (on the part of the APD, which the data indicates has adjusted its behavior by increasing enforcement).
- The enforcement surge was concentrated in Downtown (48 percent above its historical average) and the Northern District (58 percent above), and was led by warnings rather than citations.
- Six contributing factors are identified: College Avenue lane reconfiguration, K9 officer rescheduling, internal education and expectation-setting, the 2025 noise ordinance update, a towing ordinance update, and traffic grant funding directed toward Downtown.

While it is not clear from Resolution 8-R-26 what the evaluation question might be to increase compliance action, two actionable research questions should be considered when evaluating data related to noise: 1) Where should enforcement action be targeted to maximize enforcement action?, and 2) What are the effects of enforcement actions? The two central variables analyzed in the 2026 brief provide a framework in which to answer these questions. We see that most noise complaints are generated from the Downtown law enforcement district, and we have seen a marked and statistically significant increase in YTD enforcement actions taken by APD within the last year.

These data provide a shared understanding that the largest number of resident complaints occur downtown, which represents a disproportionate concentration of disturbances. We also know that the level of disturbance has been similar year over year. This indicates that while anecdotal evidence may lead residents to believe the noise is getting louder overall, the level of tolerance for perceived noise violations remain stable, based on the complaint data. This suggests that citable offenses have likely not increased. They also let us know that concentrated enforcement action to complaint-heavy districts, ordinance changes, and other applied tools are the likely cause for the marked increase in enforcement action in 2026 at a level that chance cannot explain.

B. What Enforcement Records Actually Measure

The 2026 Brief is explicit: complaint volume alone cannot explain the enforcement increase. Officers are not responding to more calls; they have been leveraging more enforcement tools in recent years. Enforcement data tracks officer behavior, not the acoustic environment.

However, enforcement records do capture something that raw acoustic sensors cannot. Each enforcement action in the APD dataset reflects an officer's on-scene determination that a violation had occurred. This means that a trained officer observed a vehicle, assessed whether its exhaust appeared modified or the overall behavior of the driver with regard to noise was unlawful, and made a legal judgment. That judgment is precisely what no automated acoustic sensor can replicate. In this respect, enforcement data has a legal quality that decibel readings lack; it represents documented unlawful incidents, not merely loud ones.

The Evidentiary Distinction

Enforcement data and acoustic monitoring data answer different questions and carry different legal weight. Enforcement records document officer-adjudicated violations. Acoustic monitoring documents sound pressure levels. No current automated system can bridge that gap without human legal determination.

IV. The Science of Measuring Vehicular Noise

Several features of environmental acoustics must be understood before a monitoring program is designed. The following draws on the ISO 1996 standard series, the international framework governing environmental noise measurement, and on recent peer-reviewed research examining measurement uncertainty in practice.

A. The Governing Measurement Standard: ISO 1996

The International Organization for Standardization's ISO 1996 series, *Acoustics: Description, Measurement and Assessment of Environmental Noise*, is the technical framework applicable to the type of program Resolution #8-R-26 contemplates. The series comprises three parts: ISO 1996-1 defines the acoustic descriptors and quantities to be measured; ISO 1996-2 specifies measurement procedures and uncertainty analysis; and ISO 1996-3 addresses impulsive and low-frequency noise, which is relevant to modified motorcycle exhausts. Any monitoring program deployed by Appleton should specify compliance with this standard from the outset.^[1]

The standard requires specification of four descriptor classes before measurement begins:

- **Leq (equivalent continuous sound level)**—average acoustic energy over a defined period. Appropriate for characterizing chronic exposure but can obscure brief extreme events.
- **Lmax (maximum instantaneous level)**—captures peak events. Most relevant to the resolution's focus on extreme incidents.
- **L10 (level exceeded 10 percent of the time)**—sensitive to frequent intrusions. Useful for characterizing the upper range of routine noise.
- **Lden (day-evening-night level)**—applies time-of-day weighting to reflect differential health sensitivity. A noise event at 11 PM carries more weight than the same event at 2 PM.

The choice of descriptor is significant: a program based on L_{eq} will yield different results and conclusions than one based on L_{max} event counts. Given that Resolution #8-R-26 mandates the City identify the frequency of extreme incidents, L_{max} combined with a threshold-based event count is the most appropriate primary metric. Before designing a measurement study, the City must define this threshold based on the specific research question it intends to address.

B. Measurement Uncertainty Is Larger Than It Appears

A 2022 conference paper published in the EUROREGIO/BNAM proceedings ^[2] directly addresses the magnitude of measurement uncertainty in road traffic noise monitoring conducted under ISO 1996-2:2017. The study found that even properly instrumented short-term measurements following the standard's prescribed procedures can diverge meaningfully from true environmental values due to:

- **Meteorological variability:** Temperature inversions, wind speed and direction, and humidity all affect sound propagation. Wisconsin's climate produces significant seasonal variability in these parameters, meaning readings taken in January and July at the same location under the same traffic conditions may not be directly comparable without meteorological adjustment.
- **Sensor placement relative to reflective surfaces:** A sensor mounted near a building facade will record systematically different levels than the same sensor in open space for identical passing vehicles. Facade mounting amplifies measured levels; open-field mounting reduces them. Both effects are real and predictable, but must be documented and accounted for.
- **Observation period length:** Short-term samples may inadequately represent the distribution of events. ISO 1996-2 requires minimum observation windows designed to capture source variability; shortened deployments produce data with wider uncertainty bands.

A 2023 interlaboratory comparison (ILC) study presented at Forum Acusticum ^[3] tested measurement performance across multiple independent laboratories using identical source conditions that included industrial noise, local traffic, and modeled predictions and found statistically significant performance differences between labs attributable to meteorological corrections, directivity assumptions, and sensor positioning variation, not instrument quality. This finding is directly applicable to Appleton—deploying technically adequate equipment is necessary but insufficient for producing reliable data. Measurement protocol standardization and documentation are equally critical.

To adequately design and measure the kind of data mandated by the current resolution, careful consideration would need to be paid to the mitigating variables outlined in this section. However, the City of Appleton employs no sound experts within its staff ranks, much less to the level of advanced expertise that would be needed to account for the necessary confounding variables. Therefore, in order to implement the data collection methodologies identified in Resolution #8-R-2026 a consulting firm would be required to design the overall project, make recommendations related to equipment to install, install sound measurement devices taking into consideration of the recommendations of the ISO report, and monitor and translate ongoingly collected data.

Practical Implication for Appleton

A monitoring program that fails to specify and document meteorological adjustment protocols, sensor placement standards, and minimum observation periods will produce data that lacks experimental validity and cannot be reliably compared across sites or years. This is not a hypothetical risk; ILC research confirms that such data inconsistencies occur even when all participating labs use calibrated, properly maintained equipment. Consequently, the program design must mandate these protocols before the first sensor is installed.

C. Frequency Weighting Matters for Modified Exhausts

Standard environmental noise measurements use A-weighting (expressed as dB(A)), which adjusts raw sound pressure levels to approximate how the human ear perceives sound across frequencies. A-weighting is the standard used in ISO 1996, the EPA, and most state environmental programs, and it is appropriate for general traffic noise characterization. A-weighting is also what is identified in the City of Appleton Municipal Code as a compliance threshold.

However, modified motorcycle exhausts and certain aftermarket vehicle systems produce substantial energy at lower frequencies that A-weighting undervalues. A monitoring program that intends to specifically capture modified exhaust events may benefit from supplementing A-weighted measurements with C-weighted measurements (dB(C)), which are more sensitive to low-frequency content. Selecting A-weighting only, when the specific concern is low-frequency modified exhaust noise, risks under-recording the most complained-about incident types.

The 2020 ROSA P / Bureau of Transportation Statistics *Noise Levels Research Synthesis*^[4], a 45-year update to the EPA's 1974 Levels Document — identifies frequency weighting selection as one of the most consequential and most commonly underdocumented variables in municipal noise programs. The synthesis recommends that programs targeting specific vehicle categories document their weighting rationale explicitly.

While frequency weighting thresholds were present before the 2025 noise ordinance refresh, they were eliminated due to the difficulty of measurement by officers in the field making traffic stops based on possible noise violations. The subjective noise measurement provision replaced this scale weighting paradigm. However, scale weighting must be considered when objectively measuring vehicle exhaust if the goal of the data collection is to achieve a complete picture of the noise problem.

Practical Implication for Appleton

A thorough study of noise must consider weighted sound pressure. However, ordinance enforcement occurs based on 1) objective readings of noise against the db(A) scale, 2) officer-implemented subjective measurement. This adds another level of complexity to the evaluation design—thorough measurement of unlawful noise production would need to include data that is not used in ordinance enforcement. The value of objectively measured noise, as outlined in the current resolution, would not have any compliance or enforcement-related value.

D. Background Noise Complicates Source Attribution

In an urban corridor like Downtown Appleton, vehicular noise does not occur in isolation. Construction equipment, HVAC systems, entertainment venues, emergency vehicles, and other non-motorized/amplified activity all contribute to measured sound levels. An automated system that counts noise events must be capable of distinguishing extreme vehicular sources from this background, or it will generate false positives that dilute the data.

This source-separation problem is especially acute in the context of Wisconsin's legal framework. Even if an automated system correctly identifies a sound as originating from a motor vehicle, it still cannot determine whether that vehicle's exhaust is modified. Source identification and legal classification are separate problems, and current technology can assist with the first but not the second.

E. Calibration Is Mandatory and Ongoing

Acoustic sensors drift over time. A monitoring program that deploys sensors and does not include a regular calibration protocol will produce data whose integrity degrades silently. ISO 1996-2 specifies calibration requirements; the program should designate responsibility for calibration, document calibration records, and establish a data quality threshold below which readings are flagged as unreliable. This is especially important for year-over-year comparisons, which the resolution implies as a use case. Here again, due consideration must be given to the ongoing operational realities of maintaining such a program (such as ongoing professional services contracts).

V. Evaluation of Methods Named in Resolution #8-R-26

One important limitation of cursory analysis below assumes that all assets would be deployed in the downtown law enforcement region, based on the language of the resolution including “in certain corridors and neighborhoods.” Based on public statements, social media posts, and other forms of social context given by the author’s resolution, the analysis focuses exclusively on the College Ave corridor. The analysis generalizes easily to the other law enforcement districts, but the cost analysis increases proportionately.

However, focusing on the Downtown Region exclusively does introduce an equity issue. Those constituents not living in the Downtown Law Enforcement District would not directly benefit from that proposed data collection project where it matters most—where they live. From a public health perspective employing principles of community-based participatory research signaled in “Method 3: Citizen[sic] Reporting Agreements,” an accurate understanding of the noise landscape in Appleton would also include other noisy, high-traffic corridors, including Richmond, Wisconsin, East College, and East Calumet.

With this limitation in mind, we review the methodologies presented in the resolution to be reviewed on their merit.

Method 1: Fixed Decibel Monitoring Stations

Permanent or semi-permanent sensors mounted at fixed locations record sound levels continuously, typically transmitting data in real time to a central platform. In order to address the lawful vs unlawful noise limitation produced by sound meters, a complete staff review of camera footage matched to the source point of sound with a timestamp, would need to be performed to make any reliable meaning of the data. Manual staff review of video footage would take hundreds, if not thousands of hours of manual review per year. Using this methodology, enforcement would not be possible, as unlawful behavior could not be traced to driver unless the license plate is visible.

Design Strength	Design Limitations
<p>Provides a continuous, uninterrupted acoustic record at each location. Data is objective, timestamped, and independent of officer availability or resident reporting behavior.</p> <p>Well-suited for identifying temporal patterns: time of day, day of week, seasonal variation. Generates the continuous baseline against which any future intervention can be evaluated.</p>	<p>The current monitoring approach fails to distinguish between lawful and unlawful noise sources, as a reading of 92 dB(A) is identical regardless of whether it originates from a legal truck or an illegally modified exhaust; furthermore, because sensor placement is high-stakes and requires strict adherence to ISO 1996-2 protocols, the program necessitates ongoing calibration and a significant investment of staff time.</p> <p>This methodology is appropriate for public health exposure assessment; however, it cannot serve as standalone documentation for enforcement purposes. To ensure year-over-year comparability, meteorological adjustment is required in accordance with both ISO 1996 standards and ILC research findings. Furthermore, the current framework lacks a baseline against which to measure the impact of recent City interventions, such</p>

Design Strength	Design Limitations
	as the streamlined noise ordinance and proactive enforcement measures.

Estimated cost: fixed monitoring

Staff performed a cursory estimation of fixed equipment cost for this strategy, based on the extrapolated costs for real world application expenditures, see Method 4: Automated Noise-Detection Technologies.

- Sound sensor costs: approximately \$3,000–\$8,000 per sensor unit depending on model capability and availability. A network of 5-8 sensors covering the Downtown corridor: approximately \$25,000–\$65,000 capital cost, including installation and software.
- Camera costs: approximately \$4,000-\$9,000. Total estimated installation costs accounting for a 1:1 installation with deployed sound sensors would range from \$25,000 to \$66,000. Cameras are critical of this strategy, given the established legal limitations that complicate the implementation of this strategy.
- Contracted costs: RFP-selected contractor ranging from \$150,000-\$200,000. This would include designing a robust evaluation plan in accordance with ISO 1996-2 scientific standards, developing measurement procedures and data interpretation training to APD and Health Department staff, consulting for City-wide communications planning, and for drafting an implementation plan and presenting plan to Council.
- Personnel costs: would range from \$92,000-\$95,000 for 1.0 FTE for legal review of the data to determine legal vs illegal activity by reviewing the noise and camera data. Real-world applications have used Assistant City Attorneys to perform this review but could be performed by a sworn police officer.
- Annual equipment operating costs (platform, maintenance, calibration per ISO 1996-2): approximately \$10,000–\$20,000.

Method 2: Temporary Mobile Monitoring Equipment

Portable sound level meters deployed by trained staff for targeted measurement campaigns at specific locations and times.

Design Strength	Design Limitations
<p>Lower capital cost and greater flexibility than fixed installations. When conducted by trained personnel following ANSI/ISO standards, produces legally defensible measurements at specific moments. Can be directed to locations and time periods identified by enforcement data or community input.</p> <p>Most useful as a supplement to fixed monitoring or automated detection at known problem locations. Can document specific</p>	<p>This monitoring approach captures conditions only when and where staff are present, which prevents it from reliably estimating the frequency of extreme events. Moreover, it remains subject to the same measurement uncertainty variables identified in ISO 1996-2 research. Consequently, meteorological conditions must be documented and systemic adjustments implemented to ensure the data is considered reliable.</p> <p>Staff-conducted monitoring shares the same gap as fixed monitoring: a decibel reading documents a sound level, not a violation. If these measurements are intended to support enforcement proceedings, a formal protocol</p>

Design Strength	Design Limitations
<p>corridor conditions during high-activity periods.</p>	<p>for the chain of custody must be established. While utilizing trained officers would eliminate the identification gap, the implementation costs would be substantial. Finally, unless this approach is used as a supplement to fixed or automated strategies, it will not be possible to establish an accurate understanding of the noise landscape in downtown Appleton.</p>

Estimated cost: mobile monitoring

Equipment: approximately \$1,500–\$5,000 for a calibrated sound level meter meeting ISO 1996-2 requirements. An estimated 3 pieces of mobile monitoring equipment would be deployed if supplementing fixed monitoring or automated monitoring strategies. Ongoing cost is primarily staff time: a targeted campaign of 20–30 deployments per year requires approximately 60–100 staff hours per unit. The allocation of staff time would depend on the desired accuracy of the data collected. Ongoing staff costs would range from \$24,000-\$40,400.

Method 3: Resident Reporting Agreements

Structured programs under which residents report noise incidents through a dedicated platform, potentially including the ability to submit audio recordings or timestamped location data.

Design Strength	Design Limitations
<p>Leverages existing resident concern and engagement. Can provide geographic and temporal information at relatively low direct cost on the collection-side. Provides qualitative context that acoustic measurements alone cannot supply. May capture incidents in areas not covered by fixed sensors.</p> <p>Useful for directing monitoring resources toward emerging problem locations and cross-referencing with sensor data where available.</p>	<p>Citizen reports are not acoustic measurements. They cannot establish decibel levels, compare events across locations, or demonstrate compliance with any threshold. They are not governed by ISO 1996 or any measurement standard, which would include only using ISO 1996 grade equipment calibrated annually. These data would be treated as complaint data on account of the lack of scientific rigor of this strategy.</p> <p>This approach is best used as a supplement to, rather than a substitute for, objective measurement. The 2026 Brief demonstrates that complaint levels have remained stable for five years despite significant enforcement changes, which confirms that citizen reports do not independently provide a reliable reflection of the noise environment. Furthermore, this method is unlikely to produce information beyond what existing complaint data already reveals, which is that</p>

Design Strength	Design Limitations
	the majority of noise events are occurring downtown.

ESTIMATED COST: CITIZEN REPORTING

Ongoing costs depend on staff capacity for review and geocoding. Staff hours would range from the hundreds to thousands, depending on the number of submissions to be geocoded. Budgeting for 200 hrs of staff time per year for geocoding, ongoing costs would be around \$9,000 per year. Displacement of other departmental priorities would need to be determined.

Method 4: Automated Noise-Detection Technologies

Sensor systems combining continuous acoustic monitoring with real-time classification algorithms, potentially integrating with cameras or license plate readers to document individual events. This method has the closest fit to the resolution’s stated goal of counting extreme incidents and the most instructive real-world track record, which is examined in detail below. However, the legal challenges explored earlier in this memo remain.

Another consideration must be considered when examining this consideration—the use of automated license plate reader technology (ALPR) for this purpose. With the recent termination of the Flock camera contract, and a recent resolution for the Common Council to examine the policies and procedures around APLR closely when deployed for traffic/code enforcement, at this time it is difficult to evaluate the availability of APLR technology to aid in the automation of noise ordinance violations.

Similar equity issues exist with this method, as they do in Method 1. Deployment of ALPR technology for the purposes of identifying unlawful noise generation within certain areas of the City, but not others, could be perceived as targeting by residents within the automated noise surveillance zone.

Although it is well beyond the scope of this memorandum to study with certainty, it is highly probable that there would be economic consequences for this method. Downtown businesses may experience a “cooling effect” if tourists and other patrons were to be deterred based on moral or ethical grounds as the local, state, and national conversation becomes amplified against certain ALPR technology vendors.

Design Strength	Design Limitations
<p>Combines the continuous record of fixed monitoring with event-level specificity. Can provide timestamped event logs, acoustic classification (motorcycle, truck, passenger vehicle), directional information, and potentially vehicle description.</p> <p>Several U.S. and international municipalities have deployed these systems specifically targeting modified exhaust violations. Real-</p>	<p>This method cannot determine whether a vehicle’s exhaust has been modified. Even with camera integration and license plate capture, no current automated system can confirm modification status in a drive-by scenario, necessitating manual review by staff. Consequently, the ultimate outcome would be functionally similar to the fixed decibel monitoring stations described in Method 1.</p> <p>Classification accuracy degrades significantly in dense urban environments characterized by overlapping noise sources. Furthermore, legal and due process questions must be</p>

Design Strength	Design Limitations
world program data is now available and directly applicable to Appleton's planning.	resolved before automated data can be utilized in enforcement proceedings. Finally, if camera integration is included in the system, it will raise critical privacy considerations.

What Real-World Programs Have Found

The New York City Noise Camera Enforcement Program established under Local Law 7 of 2024 is the most directly applicable operational evidence available in the United States. The NYC Department of Environmental Protection's 2025 Annual Report ^[5] provides full program data through its first year of citywide deployment:

Metric	Figure	What It Means for Appleton
Cameras operational	15	Deployed across 5 NYC boroughs as of 2025
Noise events recorded	15,994	Events exceeding the 85 dB(A) threshold and triggering camera activation
Summonses issued	1,691	Events resulting in an actual violation notice after human review
Violator rate	11%	89 of every 100 acoustically extreme events did not result in a violation
Personnel costs	\$492,565	Annual cost of staff reviewing flagged events and processing summonses
Vendor/equipment costs	\$109,092	Annual technology costs

THE 11% FINDING AND WHAT IT MEANS FOR APPLETON

The NYC data quantifies what this memo argues conceptually about the lawful/unlawful gap. Of approximately 16,000 acoustically extreme events exceeding 85 dB(A), roughly 89% did not result in a violation after human review. The cameras cannot determine whether a vehicle's exhaust is modified, that determination still requires human judgment. This is not a technology failure; it is an inherent structural limitation. Personnel costs in the New York City project are misleading in that it does not capture the leveraged student time related to the NYU research that supplements this program.

It is notable that NYC's legal framework differs from Wisconsin's. NYC can issue citations based on exceeding a decibel threshold regardless of exhaust modification status. Appleton cannot. Under Wisconsin law, even if the City were to deploy an identical camera system and achieve NYC's 11% adjudication rate, those adjudications would still require a separate officer determination that the exhaust is modified before a citation could issue. The effective violator rate from automated monitoring alone in Appleton's legal context would be much lower than NYC's.

A similar automated project was implemented in Knoxville, Tennessee. A pilot noise camera deployment identified approximately 1,300 acoustically elevated vehicles in its first six months of operation. [6] However, as of the reporting date, no citations had been issued from those data, because existing Tennessee state law did not provide sufficient legal authority to act on camera-generated acoustic data alone. The city is pursuing legislative authorization at the state level before the program can move to enforcement. Knoxville's situation is structurally identical to what Appleton would face: the technology works; the legal framework to act on its output does not exist.

California SB 1079, analyzed in detail by the California Senate Judiciary Committee, [7] authorized six cities to conduct pilot programs using sound-activated enforcement devices targeting modified exhaust violations. The legislative record identifies the precise gap the Wisconsin framework creates: the bill was necessary because *"enforcement has been complicated due to lack of tools for law enforcement officers,"* and the state had to explicitly authorize local programs because local authority alone was insufficient. The bill also required: equal geographic distribution of sensors to prevent targeting, data confidentiality restrictions, and an initial non-penalty phase before citations could issue. California's process illustrates the full policy pathway Appleton would need to navigate at the state level if automated enforcement is the long-term objective.

CRITICAL NOTE ON ENFORCEMENT USE

Even the most sophisticated automated noise-detection system cannot close the lawful/unlawful gap without human legal determination. Automated systems should be treated as investigative tools that flag events for officer follow-up, not as standalone adjudicators. Before any automated detection investment, the City Attorney's office would need to review: (1) whether current Wisconsin statutes and Appleton ordinance language support using automated acoustic evidence in citation proceedings, especially with active resolutions in play around this topic at the time of this writing; (2) what chain of custody and evidentiary standards would apply to all aspects of this process, including human review; and (3) whether state-level authorization similar to California SB 1079 would be required.

ESTIMATED COST: AUTOMATED DETECTION

The deployment of ALPRs at 3 high-priority Downtown locations: approximately \$60,000–\$120,000 capital cost, scaled from, and consistent with NYC vendor cost experience. Annual software licensing and maintenance: approximately \$10,000–\$20,000. Human review staffing must be budgeted separately — the NYC program required \$492,565 annually in personnel costs for 15 cameras reviewing 15,994 events. At Appleton's scale, a proportional estimate for 3 cameras would be approximately \$100,000–\$150,000 annually in personnel costs if the program moves to enforcement use, depending on the amount of staff hours required for review. Department of Transportation contract award data indicate that fully automated traffic enforcement cameras, like those identified in Resolution #8-R-2026 range from \$63,000-\$92,000 per each intersection. Three intersections puts this cost at about \$189,000-\$276,000, with an ongoing annual maintenance cost of about 10%.

Total Fiscal Impact

This table summarizes the estimated cost range for each of the four noise data collection methods named in Resolution #8-R-2026. Initial cost means the one-time, upfront cost to set up the method. Ongoing annual cost means what the City would need to budget every year after setup.

Method	Initial (One-Time) Cost Range	Ongoing Annual Cost Range
Method 1: Fixed Decibel Monitoring Stations	\$200,000 to \$331,000	\$102,000 to \$115,000

Method	Initial (One-Time) Cost Range	Ongoing Annual Cost Range
Method 2: Temporary Mobile Monitoring Equipment	\$4,500 to \$15,000	\$24,000 to \$40,400
Method 3: Resident (Citizen) Reporting Agreements	About \$9,000	About \$9,000
Method 4: Automated Noise-Detection Technologies	\$60,000 to \$267,000*	\$28,900 to \$197,600

* Method 4 initial cost reflects two different cost sources in the memo: a vendor-scaled pilot estimate based on NYC's program (\$60,000 to \$120,000), and Department of Transportation contract award data for fully automated intersection cameras (\$189,000 to \$276,000 for 3 intersections). The combined range spans both figures. The DOT-based figure is grounded in actual contract award data and may be the more reliable planning number.

** Method 4 ongoing annual cost reflects camera maintenance (about 10% of the DOT-based capital cost, or \$18,900 to \$27,600) plus software licensing and maintenance (\$10,000 to \$20,000), for a baseline pilot total of about \$28,900 to \$47,600 per year. If the program moves from pilot to active enforcement, add human review staffing of \$100,000 to \$150,000 per year, bringing the total to about \$128,900 to \$197,600 per year.

Recommendation

The Appleton Department of Public Health cannot recommend adopting the noise measurement methods proposed in Resolution #8-R-2026. This is especially true with the dramatic 2026 surge in APD noise ordinance enforcement actions as a result of recent strategic policy and systems changes in concert with multiple departments across the City administration.

Attachments

- [1]** International Organization for Standardization. ISO 1996 Series: Acoustics — Description, Measurement and Assessment of Environmental Noise. ISO 1996-1 (Basic quantities and assessment procedures); ISO 1996-2 (Determination of sound pressure levels); ISO 1996-3 (Application to noise limits). Geneva: ISO. Plain-language overview: <https://allegroacoustics.ie/guides/iso-1996-the-complete-guide/>
- [2]** Domazetovska Markovska, S., Anachkova, M., Gavriloski, V., & Changoski, V. (2022). Uncertainty Estimation in Environmental Road Traffic Noise Measurements Using ISO 1996-2:2017. Presented at EUROREGIO/BNAM 2022, Aalborg, Denmark. Available at: <https://www.researchgate.net/publication/360901663>
- [3]** Multiple authors. (2023). Uncertainties for Measured and Modelled Environmental Noise. Interlaboratory comparison study. Presented at Forum Acusticum 2023. Direct PDF: <https://dael.euracoustics.org/confs/fa2023/data/articles/000384.pdf>
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- [5]** New York City Department of Environmental Protection. (2025). 2025 Annual Report for Noise Camera Enforcement Program (mandated by Local Law 7 of 2024). Direct PDF: <https://www.nyc.gov/assets/dep/downloads/pdf/air/noise/2025-annual-report-noise-camera-enforcement-...>
- [6]** Smart Cities Dive. (2024). 'Noise cameras' aim to address vehicle nuisance complaints on city streets. Reports on NYC, London, and Knoxville deployments. <https://www.smartcitiesdive.com/news/noise-cameras-address-vehicle-nuisance-complaints-city-streets...>
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CONTACT
(<https://allegroacoustics.ie/contact-allegro-acoustics/>)

(<https://allegroacoustics.ie/guides/environmental-noise-monitoring/>) noise compliance

Understanding ISO 1996

ISO 1996 is the international standard defining how environmental noise is measured, assessed, and reported. It's the technical framework used by government agencies to regulate noise impact, but without setting fixed limits. This guide explains how ISO 1996 is applied in Ireland.

 February 6, 2026

Stephen Kearney (<https://allegroacoustics.ie/experts/stephen-kearney/>)

Industrial Noise Control (<https://allegroacoustics.ie/services/industrial-noise-control/>)

ISO 1996 forms the basis for environmental noise surveys, monitoring, (<https://allegroacoustics.ie/guides/noise-compliance-monitoring/>) noise mapping (<https://allegroacoustics.ie/guides/noise-modelling-and-noise-mapping/>) and planning assessments. Its guidelines are used in industrial and infrastructure projects, as well as urban development. While it is referenced across the acoustics and noise control industry, and implemented by regulators and planning authorities, it is often misunderstood and often applied inconsistently.

ISO 1996 does not set noise limits, that's the job of the Environmental Protection Agency, (<https://www.epa.ie/>) it defines how noise data should be collected, measured and analysed. It describes acoustic descriptors, measurement procedures, and assessment in broad concepts, allowing the authorities in each country to make decisions about potential impact in the long-term. This distinction is important. It's how we describe physical sound predictions. It's how we describe basic assessment procedures.

How is environmental noise measured?

Environmental noise is measured using standardised methods set out in the ISO 1996 series. The objective is to produce repeatable data, using scientific methods, that can be defended in a regulatory assessment or a planning decision. A licenced facility in Dublin gets the same measurement as a facility in Cork, and this matters when meeting licence conditions means so much.

Measurements are expressed using defined acoustic descriptors. The most common descriptor, equivalent continuous A-weighted sound pressure level (LAeq,T), represents the average sound energy over a specified time period. Maximum sound pressure levels (Lmax), are used to capture short-duration high-level events, while statistical descriptors, LA90,T for example, are used to establish background noise levels (the sound level exceeded for 90% of the measurement period).

Field measurement equipment has to meet the performance requirements specified in ISO 1996. The standards define how sound level meters and other instruments are calibrated, where microphones should be positioned, and how weather conditions, ground effects, and nearby surfaces influence results. Wind speed, rainfall and temperatures are also addressed.

The International Organization for Standards

“Standards define what great looks like, setting consistent benchmarks for businesses and consumers alike – ensuring reliability, building trust, and simplifying choices. Making lives easier, safer and better.”

The International Organization for Standardization, ISO, is an independent, non-governmental body that develops international standards across a wide range of industries and technical disciplines. Its role is to provide a common technical language; everyone plays by the same rules. Organisations, regulators and professionals, wherever they are, work with the same definitions, the same methods, and the same performance criteria.

In technical fields, this consistency is critical. Data can be compared in different locations, and on different projects, allowing regulators to assess compliance using scientifically, and internationally recognised methods. In an industrial context, ISO standards provide regulators with measurements and assessments (<https://allegroacoustics.ie/guides/workplace-noise-regulations-in-ireland/>) based on validated procedures rather than local interpretation.



ISO 1996 Series

Acoustic Description, Measurement and Assessment of Environmental Noise

ISO 1996 is a multi-part standard; together, the series provides a complete technical framework, each addressing a specific stage of environmental noise assessment; defining acoustic quantities, field measurement, the treatment of different sound characteristics.

ISO 1996 PDF Download

The following documents contain the full technical requirements, definitions, equations and procedures related to environmental noise. For consultants and operators, access to the original standards is important when preparing environmental noise surveys, (<https://allegroacoustics.ie/services/acoustic-testing-noise-surveys/>) compliance reports and planning noise assessments. (<https://allegroacoustics.ie/services/planning-noise-assessment/>) Each part of the series is published separately and should be used together where a complete assessment is required.

click here to download ISO 1996-1 (<https://allegroacoustics.ie/wp-content/uploads/2026/01/ISO-1996-Allegro-Acoustics.pdf>)

click here to download ISO 1996-2 (<https://allegroacoustics.ie/wp-content/uploads/2026/01/ISO-1996-2-Allegro-Acoustics.pdf>)

click here to download ISO 1996-3 (<https://allegroacoustics.ie/wp-content/uploads/2026/01/ISO-1996-3-Allegro-Acoustics.pdf>)

ISO 1996 1

Basic Quantities & Assessment Procedures

ISO 1996-1: 2016 defines the acoustic quantities used to describe environmental noise and sets out the basic assessment procedures for noise exposure; how sound pressure levels are expressed, how time intervals are defined, how noise descriptors are selected for different assessments of environmental noise. The standard also introduces the concept of adjusted levels and rating levels, where penalties are added to account for sound characteristics, tonality or impulsiveness for example.

$L_{Aeq,T}$ - equivalent continuous sound levels,

L_{max} - maximum levels, and statistical levels such as

$L_{A,T}$ - defined background noise.

ISO 1996 2

Determination of Sound Pressure Levels

ISO 1996-2: 2017 sets out the technical methods for determining sound pressure levels in outdoor environments. It defines how measurement activities are planned, executed, and analysed. This document specifies instrument performance, including calibration and verification of sound level meters. It also specifies microphone positioning, measurement locations and minimum distances. Detailed guidance is provided on meteorological conditions; wind speed, precipitation and temperature.

ISO 1996-2 also makes the distinction between long-term unattended monitoring, and short-term attended measurements. Measurement uncertainty is explicitly addressed, reinforcing the importance of traceable and defensible data.

ISO 1996 3

Objective method for the measurement of prominence of impulsive sounds & for adjustment of L_{Aeq}

ISO/PAS 1996-3: 2022 provides an objective method for identifying impulse sound and whether an adjustment should be applied. This part addresses a longstanding challenge in environmental noise, where sound characteristics can increase perceived “annoyance” without necessarily increasing average sound levels.

ISO 1996-3 provides for consistency and transparency when dealing with industrial noise sources; metal handling, pressure release events, intermittent mechanical impacts etc. It provides a clear technical basis for adjustment decisions where impulsive sound is a relevant consideration.

Industrial Noise Control

For operators in regulated environments, noise control depends on accurate methods, accurate data and experienced interpretation. We apply the principles of ISO 1996 in practice. Our clients can make decisions that protect their neighbours, deliver compliance and allow operations to continue uninterrupted.

Sound Insulation Testing

Effective noise control relies on standards. (<https://allegroacoustics.ie/services/industrial-noise-control/>) It requires acoustic expertise to assess environmental noise; designing measurement programmes, interpreting results correctly and translating those results into practical control measures. This is the value of experienced acoustic engineers, (<https://allegroacoustics.ie/guides/what-is-an-acoustic-engineer/>) this is the value Allegro Acoustics provides.

We work in every industrial sector, to apply ISO 1996 correctly in real-world conditions. Our work produces data that stands up to regulatory scrutiny and supports long-term operational stability. If your facility operates in a noise-sensitive environment, or you need to meet licence requirements, specialist acoustic input is essential for you. Click here to speak to an expert... (<https://allegroacoustics.ie/contact-allegro-acoustics/>)

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Domazetovska Markovska, Simona & Phd, Maja & Gavriloski, Viktor & Changoski, Vasko. (2022). Uncertainty estimation in environmental road traffic noise measurements using ISO 1996-2:2017. When measuring the road traffic noise, the environmental noise levels are quantitatively described using the equivalent noise pressure level parameter (L_{eq}). The value of L_{eq} based on the measurements done with sound level meter would probably differ from the true one due to the sources that can cause measurement uncertainty. According to this, the ISO 1996-2:2017 standard proposes calculation of the standard measurement uncertainty, so that the results from the measurements could be more accurate. This paper proposes a guideline on estimating the measurement uncertainty in compliance with the ISO standard for short-term measurements of road traffic noise. To verify the proposed method, twenty short-term measurements are done in same spot in morning and afternoon period from Monday to Friday for two weeks; and afterwards, the measurement uncertainty is calculated for each measurement. To confirm the accuracy of the results, additional acoustic modeling was made. By comparing the results for the parameter from the measurements and from the acoustic noise maps in accordance with the calculated measurement uncertainty, it could be confirmed the results accuracy. In conclusion, this paper presents a reflection on why estimation of the uncertainty of the measurement is essential in environmental noise analysis.



UNCERTAINTIES FOR MEASURED AND MODELLED ENVIRONMENTAL NOISE PARAMETERS FROM INTERLABORATORY COMPARISON

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ABSTRACT

In this paper the results of interlaboratory comparison (ILC) in the field of environmental noise parameters measurements according to ISO 1996-2:2017 without (41 labs) and with meteorological conditions at 10 m together with modelling results according to ISO 9613-2:1997 (10 labs) and EU-CNOSSOS method (7 labs) are presented. The two measurement situations are considered, simulated industrial site with loudspeaker inside the building and local road. The industrial site noise parameters are measured at two positions (25m in free field and at 50 m in front of reflection surface). Traffic noise levels are measured in the free field at 100 m distance. The environmental noise levels are obtained under the different influence of residual noise from nearby highway and local activities during the day period. The measurement results for A-weighted equivalent sound pressure levels ($L_{Ae,eq}$), A-weighted spectrum for industrial noise site and in addition sound exposure levels (L_{AE}) for each individual pass-by of vehicles with their standard deviations and measurement uncertainties for each traffic category are shown with determined meteorological conditions. The measurement results at reference points are later used in modelling the industrial noise source and local road at other defined positions with results of modelling expressed in terms of

sound power and sound descriptors with reported and calculated measurement uncertainties for complete ILC.

Keywords: *interlaboratory comparisons, environmental noise parameters measurement and modelling, industrial site and local road, measurement and modelling uncertainties, meteorological conditions.*

1. INTRODUCTION

The accreditation procedure according to ISO 17025:2017 for laboratories that are doing acoustic measurements (in the field of environmental noise, is a tedious task due to different approaches of different labs to the same problem (sound source) [1]. Quality control is the main motive for individual laboratories to cooperate within the ILC, but this can be used to make detailed analyses of all individual results of laboratories included in environmental noise parameter measurements and modelling. All these laboratories certify the environmental noise parameters from different noise sources (industrial and small workshop sites, road, rail, and air traffic). The motivation for this organization was the change of the standard ISO 1996-2:2017[2] to see how the different laboratories approach to the same problem.

1.1 Measuring scheme

Croatian Acoustical Society organized in ILC with 44 registered participants in the field of stable industrial source measurement at two different positions (first where Eq. 11 from ISO 1996-2:2017 standard is fulfilled and second where it is not fulfilled) [3]. The results are acquired

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from 41 of 44 labs for a stable industrial source installed in the house with one opened window and from 11 of 15 labs when local road traffic noise parameters are measured. The stable industrial pink noise source with 10 kHz tone was installed in the room in one house simulating industrial source according to the Figure 1.

Results for residual noise and when the source is turned on are shown, with experimental measurement uncertainties which are compared with reported uncertainties from labs obtained by repeating measurements in short intervals. The measurement situation is shown in Figure 1.

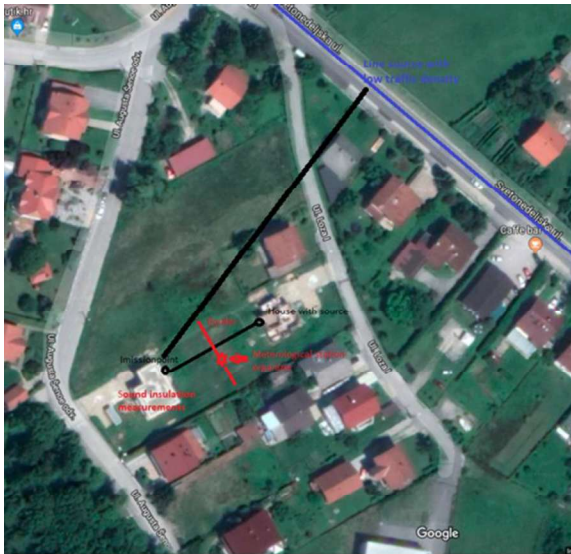


Figure 1. Measurement situation for stable source and local road with location of sources and imission points).

In this report, only the main measured values are considered measured $L'_{A,eq}$ at two different positions between houses when the source is turned off and on, rated $L_{RA,eq}$ when the source is turned on, and A-weighted spectral values when the source is turned off and on.

When local traffic road is considered the results are acquired from 20 labs for A-weighted equivalent sound pressure level and from 16 labs for L_{AE} , $L_{A,max}$ for each vehicle category type because local road traffic was not so dense and it was possible to distinguish individual vehicle categories and study the statistics.

In addition, the meteorological conditions measured from labs and organizers at 10 m should be related to measured noise samples from the source when the noise levels are measured at position 2 (eq. 11). standard [2] is not satisfied). The measurement uncertainty for all parameters (with excluded outliers) is calculated in the form of standard deviations and experimental measurement uncertainty (depending on the number of samples).

1.2 Modelling scheme

The results of measurements at two positions from stable source and one position from local road source are used in modelling the environmental noise levels at other positions. The calculation models for stable industrial source were ISO 9613-2:1997 [3] and EU-CNOSSOS [4] and for local road observed as line source was NMPB 2008 [5] and EU CNOSSOS. The modelling scheme is shown in Figure 2.



Figure 2. Modeling scheme for stable and local road as line source with measurement positions as reference and new objects and additional positions.

2. MEASUREMENT AND MODELING SITUATION

Measured data have been analyzed in detail and measurement data are used in model calibration.

2.1 Measurement situation

Laboratories have recorded several noise samples in different time intervals (several samples usually 5 with 1 min-15 min duration) at two different positions (free field and in front of reflecting surface) and they averaged the

results regarding their duration and found standard deviations as described in [2].

There was a problem with tonality at measurement position S1P1, S1P2 because some laboratories had tonal correction and some not. The problem with 10 kHz tone is large directivity of the source at that frequency so slightly changed position can have significant influence on K_T . In final comparison for $L_{RA,eq}$ the tonal component was removed from labs which reported tonal penalty.

The stability of source is checked by measuring sound pressure level in the room at the same place before and after measurement session of each lab and experimental uncertainty for $L'_{A,eq}$ was $u=0,03$ dB.

The meteorological data are measured during the intervals when noise is measured at S1P2 (form industrial source) and S2P3(local road with mixed traffic) when equation 11. from standard ISO 1996-2:2017 is not satisfied. Measured meteorological data in noise samples intervals are (wind speed, wind direction, temperature, pressure and humidity at 10 m height or on the height of microphone (for labs which do not have possibilities to measure meteorological conditions at 10m height).

Meteorological parameters have been measured by organizer for each lab which have meteorological station and for all other participants which do not have meteorological station. For some which do not have meteorological station the meteorological data are compared and compared with obtained meteorological windows [2]

2.2 Modelling situation

Laboratories have been measuring noise from the stable source at two predefined positions: first on the border in the middle between houses and second in front of the facade with necessary correction due to position near reflecting surface [2]. One lab (Lab21) has chosen additional measurement positions from stable source in the directions of newly installed objects to account source directivity. Other labs haven't considered plane source directivity (it is not reported) so their results (Lab21) without plane source directivity is taken into comparison. In standard ISO 1996-2:2017 [2] it is explicitly written that for complex sources the directivity of the source in different directions when model is calibrated should be considered.

Laboratories have recorded several noise samples in different time intervals (usually 5 or 10 samples with 1-15 min duration) at two different positions (25 m and 50m) and they averaged the noise

samples regarding their duration and standard deviations given in the standard ISO 1996-2:2017 and excel tables. This was done to calibrate the considered acoustic models for stable source and local road. each lab measured the local road traffic noise usually for 60 min in one or two calibration points [7] and sound exposure levels (L_{AE}) for each individual event of interest (light, medium and heavy vehicle pass-by) has been determined.

The laboratories have measured the environmental noise parameters from local road at one predefined position (Pos3 in ILC-1-2019) at 4 m height and some have chosen closer measurement position to the local road (7,5 m from the road or at the position between the predefined measurement position or line sound source ≈ 50 m). They provided the number of different types of vehicles (light, heavy and medium).

The labs have used the measured equivalent sound pressure level to estimate sound power from the sources and find new equivalent levels at four additionally defined positions.

2.3 Measured and modelled parameters

Measured noise parameters when the source is turned on are:

$L'_{A,eq}$ (dB(A)) and $L_{RA,eq}$ – measured and rated A-weighted equivalent sound pressure level (corrected to free field conditions), corrected due to influence of measurement position and residual noise.

L_{WA} (dBA) - sound power of the sources (unknown but it can be determined from the calibration measurement at predefined positions).

In addition, the sound descriptors $L_{d(ay)}$ for stable sound source and traffic environmental noise parameters during the measurements (usually 1h) are found (from counted number of vehicles). The organizer provided the average number of vehicles for day, evening and night period and participants should determine the equivalent sound pressure levels and sound descriptors L_{day} , $L_{evening}$, L_{night} and L_{den} .

2.4 Statistics

The experimental measurement uncertainty was found using Eqn. (1) when measured quantities are converted to relative numbers and vice versa [2]:

$$u(x_i) = 10 \cdot \log_{10}(10^{0,1 \cdot L_k} + S(x_i)) - L_k \quad (1)$$

where L_k is energy averaged sound pressure level of N_m independent measurements in the meteorological and emission window according to Eqn. 2 [2].

$$L_k = 10 \cdot \log_{10} \left(\frac{1}{N_m} \cdot \sum_{i=1}^{N_m} 10^{0.1 \cdot L_i} \right) \quad (2)$$

This equation is valid only if each of the independent measurements last equal time. If the independent measurements last non-equal in time, then additional time weighting should be used when calculating averaged value according to the eq. (6).

2.5 Detection of outliers

Cochran's test is used to check if there are cell standard deviations of several ($n \geq 5$) independent measurements exceptionally large and would inflate the estimate of the repeatability standard deviation if retained.

Grubb's test is used to check if there are means in laboratory results that are exceptionally high or low and would inflate the estimate of the reproducibility standard deviation if retained.

3. RESULTS

The results section is divided in sections for stable source (residual noise and when the source is turned on), meteorological conditions, A-weighted sound pressure levels for local road, sound exposure levels for each category and modelling results for descriptors with experimental uncertainty.

3.1 Measurement results for stable source

Results in this report are shown only for A-weighted values when the source is turned off and on for two different positions.

3.1.1 Residual noise measurement results

The experimental measurement uncertainties for each lab (by using Eq. 2) are shown in Figure 3 together with reported A-weighted spectrum).

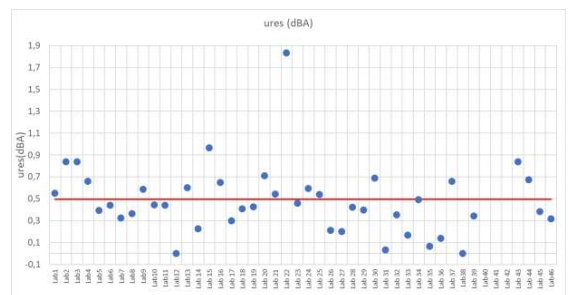
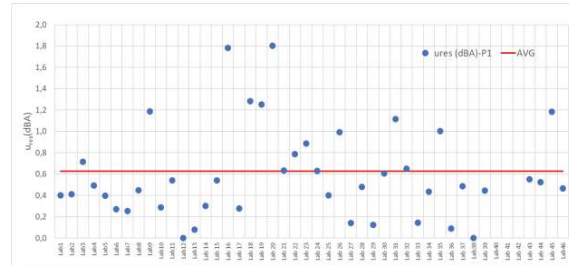


Figure 3. Experimental measurement uncertainties for residual noise measurement results at two different positions (25 m in free field and 50 m in front of the reflecting surface) and A-weighted spectrum.

It is evident that there is no significant difference between experimental measurement uncertainties for two different positions ($u(L_{res})$ at S1 and 2 even P1 is in free field and P2 in front of reflecting plane). Some labs haven't shown the A-weighted spectrum (determination of possible tonal penalty was problematic in that case)

3.1.2 Stable source measurement results

The same parameters are observed when the source is turned on. Some labs corrected the level and added tonal penalty in each sample and some have done averaging for all samples and correction for all samples. The results for rating levels are shown in Figure 4 at two different positions.

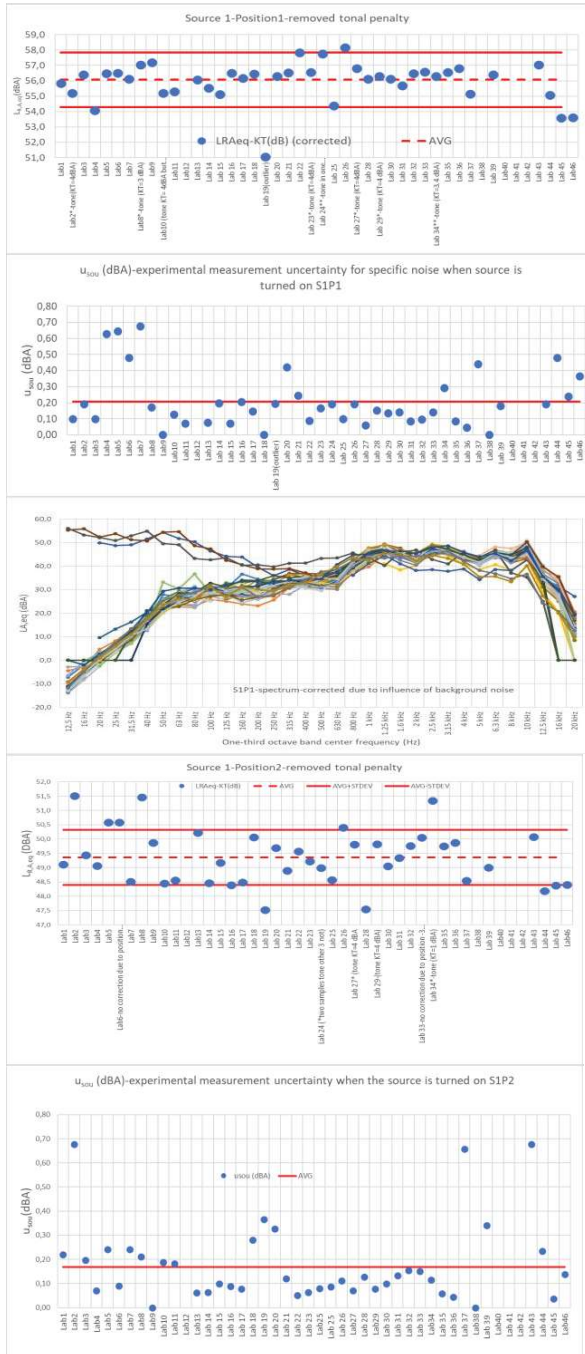


Figure 4. Measurement results for $L_{R,eq}$ at two different positions (25m free field and 50 m in

front of the reflecting plane) with experimental measurement uncertainties.

It is interesting that average value of experimental measurement uncertainty (u_{meas}) at position 2 is almost equal than at position 1 due to directivity of plane source in near field at higher frequencies because the tone is inserted in the signal (10 kHz). Some labs reported tonal penalty at 10 kHz depending on their location at position 1 (in front of the plane source or little beside) due to source directivity at 10 kHz frequency. The majority of labs haven't reported tonal penalty so the tonal penalty was removed and rating levels (corrected due to residual noise are shown).

All the measured parameters should have been corrected due at P2 to influence of reflection (-3 dB) The labs provided residual noise and spectrum spectrum data without correction due to position (just corrected due to influence of background noise in agreement with organizer). This was done by organizer to obtain comparable results.

In A-weighted spectrum the tone at source 1 measurement position 1 is visible and also some labs reported the Z(ero)-weighted spectrum due to restriction in their instruments (A-weighting is not done in instrument and additional calculations should be done in software). The results for parameters (averaged values) with standard deviations and overall experimental measurement uncertainty are shown in Table 2.

Table 2. Overall results from labs without outliers for measured parameters.

Parameter	AVG (dB)	STDEV (dB)	Number of participants	u (dBA)
$L'_{A,eq}$ -Residual noise -SIP1	43,6	2,1	41	0,3
$L'_{A,eq}$ -Residual noise -SIP2	44,4	2,3	41	0,4
$L_{RA,eq}$ - Source noise- SIP1	56,1	0,9	41	0,1
$L_{RA,eq}$ -Source noise SIP2	49,4	1,1	41	0,2

3.1.3 Meteorological conditions during measurements of stable source at SIP'' position

The laboratories put their meteorological station near to organizer and meteorological windows obtained by organizers and the results for meteorological windows are

shown in Table 2. The majority of labs don't have meteorological station because they measure the noise levels at short distances so the organizer determined meteorological windows for them in accordance to Table 4 and ANNEX A from ISO 1996-2:2017. The participants measured the noise levels during day period between 8:00-19:00. Each lab come at different day and time period to have different influence of residual noise.

Table 2. Compared meteorological windows from participants and organizer during measurement interval when measurements are done at S1P2 position.

Lab	Org-Window-Table 4.	Org-Window-Annex-A	Participant-Window-Table 4.	Participant Window-Annex-A
1	M1	M1		
2	M1	M1	M1	M1
3				
4	M1	M1	M1	M1
5	M1	M1		
6	M1	M1		
7	M1	M1		
8	M2	M3		
9	M1	M2	M1	M2
10	M1	M1	M1	M1
11	M2	M1		
13	M1	M2	M1	M2
14	M1	M2		
15	M1	M1	M1	M1
16				
17	M1	M1	M1	M1
18				
20	M1	M2	M1	M2
21	M1	M1	M1	M1
22	M1	M1		
23	M1	M2	M1	M2
25	M1	M1	M1	M1
27	M1	M1		
28	M1	M2	M1	M2
29	M1	M1		

30	M1	M1	M1	M1
32	M1	M1		
33	M1	M1		
35	M1	M1		
37	M1	M2	M1	M2
45	M1	M3	M1	M3
46	M1	M1	M1	M1

Most participants haven't averaged the meteorological data in intervals when noise samples from the source are obtained or just provided the list of data without determination of meteorological windows. Some stations perform the scalar averaging of wind speed not vectorial.

3.2 Measurement results for local road traffic

The local road noise levels are measured at distance 100 m from the road (open area, soft ground). In addition to $L'_{A,eq}$ and $L_{A,max}$ parameters the sound exposure levels for each vehicle category is determined with their uncertainty and this location. The traffic was not so dense so individual pass-by of different vehicle categories are distinguish according to figure 5 (logging data during measurements) and by the L_{AE} parameters are determined for each lab with experimental measurement uncertainty.

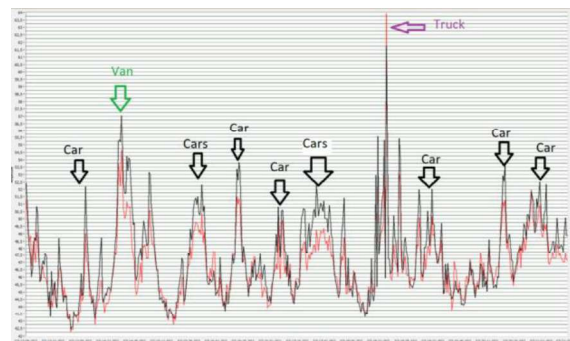


Figure 5. Logging $L_{Aeq,1}$ s data during pass by of vehicles and distinguishing different type of vehicles (S2P3 at 100m and control position at 40 m distance).

The results for measured $L'_{A,eq}$ levels from local road with $L'_{A,95}$ and L_{AE} for each vehicle category are shown in Table 3.

Table 3. Measurement results (overall AVG without outliers) for traffic noise parameters with experimental measurement uncertainties and number of observed vehicles.

Parameter	AVG (dB)	STDEV (dB)	Number of participants	u (dBA)
$L_{RA,eq}$	45,6	2,3	20	0,5
$L'_{A,95}$	38,9	2,8	19	0,6
$L_{AE}-L$	50,7	3,1	15	0,8
$L_{AE}-M$	55,4	2,3	16	0,6
$L_{AE}-H$	60,8	3,2	16	0,8
$L_{A,max}-L$	48,7	3,8	16	1,0
$L_{A,max}-M$	50,5	3,6	16	0,9
$L_{A,max}-H$	55,8	3,9	16	1,0

*L-light, M-medium, H-heavy

Some labs didn't want to analyze passing-by vehicles as individual events, so they just send the overall measured value. Two labs (17,27) didn't have logging, so they have done the analysis by observing individual pass-byes of different vehicles categories. It is evident that obtained experimental measurement uncertainties for $L_{A,eq}$ are much lower than suggested in ISO 1996-2:2017 (eq. 12 and 13.) under typical meteorological windows during the day period.

3.3 Modeling results

3.3.1 Stable source

The laboratories used measurement results at closer position to calibrate the model (determine sound power of the source) and then used that data to recalculate the noise levels at other locations.

The results for stable source sound power with modelling uncertainty are shown in Table 4.

Table 4. Overall results and experimental uncertainties for stable industrial source obtained by two modelling methods.

	AVG - ISO 9613-2:1997 (dB)	u(dB)-ISO 9613-2:1997	AVG-EU-CNOSSOS (dB)	u (dB)-EU CNOSSOS
S1-power	88,2	1,2	90,6	1,3

L_d-1	45,4	0,6	46,4	0,4
L_d-2	45,3	0,7	44,1	0,6
L_d-3	51,5	1,5	51,9	1,0
L_d-4	48,6	0,6	48,2	0,6

It is evident that approximately the same modeling uncertainties are obtained for two different methods and when compared with reported modelling uncertainties from labs they are much lower.

3.3.2 Local road source

In this part the two different approaches have been tested. In first laboratories used measurement data at S2P3 position to calculate noise levels at other positions with number of vehicles during measurement and in other approach only the model has been calibrated with the measurement results and organizer provided the number of vehicles (day, evening night period) to calculate sound descriptors.

The results for number of vehicles during measurements, sound power is and descriptors L_d for two positions during day period are shown and Table 5.

Table 5. Modeling uncertainty for different methods of calculation (NMPB-XPS-12 and CNOSSOS EU-8).

	AVG (dB)-NMPB	u(dB)-NMPB-XPS	AVG (dB)-CNOSSOS	u(dB)-CNOSSOS
S2-power	79,9	0,8	77,7	0,6
L_d-1	46,8	0,9	44,3	0,7
L_d-2	43,4	1,0	41,5	0,6
L_d-3	40,8	1,8	38,1	1,6
L_d-4	41,6	1,5	40,0	1,0

The same procedure is repeated for defined number of vehicles during different periods and the results for modelling with different methods are shown in Table 6.

Table 6. Modelling results and uncertainties with given number of vehicles during day ($N_{light}=600$ /hour , $N_{medium}= 48$ /hour, $N_{heavy}=12$ /hour).

	AVG-NMPB	u(dB)-NMPB	AVG-CNOSSOS	u(dB)-CNOSSOS

S2-power	73,9	0,6	79,4	0,6
L _d -1	49,0	0,5	46,1	0,6
L _d -2	45,5	0,6	43,2	0,5
L _d -3	43,3	1,2	40,8	1,2
L _d -4	44,6	0,8	42,0	1,1

It is visible that with the same data the sound descriptors obtained by CNOSSOS method are lower than compared to the NMPB-XPS method. The modelling uncertainty for all results is significantly lower than reported from the participants (stable and local road source sound power u form 2 dBA to 2,5 dBA, sound descriptors from 2 dBA to 3,5 dBA.

3.3.3 Influence of meteorological conditions on modelling results

All laboratories measured noise levels in neutral on unfavorable conditions during day period and have not corrected the modelling results according to favorable or very favorable conditions.

4. CONCLUSION

Few general remarks are noted for stable source, local road source and meteorological conditions. u_{sou} parameter should be always determined closer to the source and not far away due to influence of other conditions (meteorology, measurement location, absorption in air, reflection from ground). Some laboratories have not apply A-correction on their measurement data so it can be problematic to determine tonal correction K_T which is visible in spectrum when the source is turned on. Also, the A-weighted spectrum is not provided when the background noise is considered. Some labs have not use vectoral averaging but scalar averaging and wind velocity are not averaged in correct manner (as vectors in each interval of noise sample observation). There were no possibility to obtain M3 and M4 meteorological windows during day period. The overall experimental measurement uncertainty u was much lower than suggested isn standard ISO 1996-2:2017 according to $u_{\text{met}}=2$ dBA. When plane source is considered, the directivity should be also taken into account (Lab21 has reported the results assuming directivity of plane source and when directivity is not included into account). Other labs haven't reported that they accounted directivity of the source and that they haven't checked the directivity by measuring sound pressure levels in different directions from plane source.

Some participants didn't want to calculate sound exposure levels for each traffic vehicle category so just reported the overall level during measurement with excluded some residual noises. Some labs are not provided modelling uncertainty and spectrum of the source power for comparison. It is observed that sound power of CNOSSOS method is slightly lower compared to the situation when XPS-NMPB2008 method is considered.

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Noise Levels Research Synthesis

Review and Updates to Findings in *Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety*

Final Report — July 2019



U.S. Department of Transportation
John A. Volpe National Transportation Systems Center

Volpe

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Noise Levels Research Synthesis

Contents

Executive Summary.....	4
Glossary of Terms.....	7
1 Introduction	11
1.1 Background on the Levels Document	11
1.2 Introduction to Noise	12
2 Analysis of Adverse Effects	18
2.1 Hearing Loss	20
2.2 Activity Interference	29
2.3 Annoyance	33
2.4 Health and Sleep Impacts	45
2.5 Cognitive Effects	56
2.6 Financial Impacts.....	62
3 Analysis of Special Noise Sources	66
3.1 Impulse Noise.....	66
3.2 Stationary Noise Sources	73
4 Gap Analysis and Recommendations.....	83
Annotated Bibliography	88

Executive Summary

This document synthesizes findings from major publications on the adverse effects of noise and sound levels to protect public health and welfare, and compares those findings to *Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety* (published in 1974 by the Environmental Protection Agency and herein called the Levels Document). The primary goal of this work was to identify research that confirms, modifies, replaces, or fills in gaps in the Levels Document.

ANALYSIS OF ADVERSE EFFECTS

The table on the next page summarizes research findings in the Levels Document and recent research on adverse effects to noise from typical sources such as aviation, highway, and rail.

Hearing loss and activity interference (specifically speech interference) were the best-understood adverse effects of noise when the Levels Document was published. Little new research has been performed in those areas since 1974.

The Levels Document associated the noise levels provided for hearing loss or activity interference to other adverse effects of noise such as annoyance, sleep, health, and cognition. Substantial research has been conducted over the past 45 years that improves understanding of each of these adverse effects. In addition, this report includes findings on the financial impacts of noise on property values, which was not addressed in the Levels Document.

ANALYSIS OF SPECIAL NOISE SOURCES

This report includes an overview of impulse and stationary noise sources in a separate section, as they tend to have different noise characteristics than typical transportation noise sources.

The effect of impulse noise on hearing was well understood in the Levels Document and remains relevant today. Studies on annoyance to impulse noise from non-aircraft sources are limited. There is renewed interest in research on annoyance from supersonic aircraft, including developing aircraft designs that reduce sonic boom overpressures, as well as assessing community response.

Stationary sources described in this report include quarries, rail yards, industrial sites and temporary construction, wind turbines, and commercial space launch sites. The noise characteristics within and among these sites vary substantially in noise levels, sound quality, times of operation, and locations. The most effective method for reducing impacts of noise in communities surrounding stationary noise sources is effective land use planning.

SUMMARY OF NOISE LEVELS RESEARCH FINDINGS FOR ADVERSE EFFECTS TO NOISE

	Effect	Levels Document	Levels Document Key Assumptions	Recent Research
Noise Effects Best Understood in Levels Document (1974)	Hearing Loss	$L_{Aeq(24)} \leq 70$ dB all areas	Protects nearly the entire population from hearing loss from 40 years of continuous exposure	Little new research on noise induced hearing loss. Occupational noise standards use different assumptions
	Activity interference	Residential Areas: $L_{dn} \leq 45$ dB indoors $L_{dn} \leq 55$ dB outdoors	Protects 95-100% speech intelligibility, with a margin of safety	Protective noise levels likely have not changed
Noise Effects Not Well Quantified when Levels Document was Published	Annoyance	Residential Areas: $L_{dn} \leq 45$ dB indoors $L_{dn} \leq 55$ dB outdoors	Assumed protection against speech interference protected against annoyance; Insufficient annoyance evidence	Percent highly annoyed can range from 10% to 70% at the same noise exposure level
	Sleep Impacts	$L_{dn} \leq 45$ dB indoors $L_{dn} \leq 55$ dB outdoors	Maintaining $L_{dn} \leq 55$ dB outdoors will provide $L_{dn} \leq 40$ dB indoors; nighttime portion of L_{dn} will be approximately 32 dB, which should protect against sleep interference in most cases	Across transportation noise sources, higher levels of noise associated with increased likelihood of being awakened and higher self-reported sleep disturbance.
	Health Effects	$L_{Aeq(24)} \leq 70$ dB all areas	Assumed protection against hearing loss protected against other health effects.	Noise levels lower than those necessary to cause hearing loss can lead to other negative health outcomes
	Cognitive Effects	$L_{Aeq(24)} \leq 45$ dB indoors $L_{Aeq(24)} \leq 55$ dB outdoors	Assumed protection against speech interference was the key consideration in educational areas	Increase in noise is associated with short and long-term memory issues, reduced reading comprehension, and lower test scores
	Financial Impacts	Not Addressed	Not Applicable	Increase in noise is associated with a decrease in property values; magnitude is inconclusive

GAP ANALYSIS AND RECOMMENDATIONS

Although many of the adverse effects to noise and special noise sources have been studied, consistent, conclusive results have not been obtained and questions remain. Recommendations for future research are listed below.

- ❖ Conduct longitudinal studies to improve understanding of the effects of cumulative noise exposure on **human hearing**.
- ❖ Improve understanding of the relationship between **activity interference** and annoyance, as interference with certain activities may cause more annoyance than other activities.
- ❖ Account for confounding factors in quantifying percent highly annoyed. Despite the wealth of **annoyance** survey data available, there are large discrepancies in correlations derived from different data sets. Study distributions of confounding variables to understand their overall effect. Develop systematic corrections for non-acoustic factors in order to reduce variance in study data, e.g., selection of study questions, rating scales of annoyance, and other study design elements should be repeated across studies.
- ❖ Assess **noise metrics** used to describe annoyance, sleep impacts, and health to capture the qualities of sound that most appropriately relate to the adverse effects.
- ❖ Understand and use new types of large-scale data collection to assess **sleep impacts**, such as actigraphy to measure sleep based on wrist movements.
- ❖ Substantiate the relationship between noise exposure and **health outcomes** through consistent, repeatable studies. Consider how the relationship between noise exposure and health may change across different demographic subgroups (e.g., age and socioeconomic status).
- ❖ Determine the relative impacts of different **interventions**. Encourage interventions that have a greater benefit for the same amount of noise reduction.
- ❖ Study how road, rail, and other noise sources affect **cognition** in both home and school environments.
- ❖ Account for differences in study factors (e.g., geography, housing types, and noise sources) to understand how much noise affects **property values**. Seek opportunities to study the financial impacts of noise before and after a change in noise exposure (i.e., natural experiment method).
- ❖ Conduct more repeatable studies on **annoyance to non-aircraft impulse noise** in order to improve understanding of the exposure-response relationship.
- ❖ Continue to build knowledge on **supersonic aircraft noise**.
- ❖ Support effective **land use planning** techniques.
- ❖ Build understanding on the possible effects of noise from **wind turbines** on humans.
- ❖ Continue to study and refine models and methods to assess noise and community impacts from **commercial space launches**.

Glossary of Terms

Ambient Noise/Sound

The noise level in an environment or an area from all sources. This can include nearby transportation sources, utilities in or outside of buildings, fans, music, and other sources.

Amplitude

The pressure differential between the peak pressure of a sound wave and the atmospheric pressure.

Amplitude Modulated Noise

A type of steady state noise in which the overall amplitude rises and falls in a regular, periodic pattern. This type of noise can be heard near wind turbines, where the sound of the vibrations of the blades gets louder and softer periodically as the turbine rotates.

A-weighting

Frequency-dependent weighting filter that is used to correct measured or calculated sound to approximate the human hearing system's sensitivity to different frequencies when the unweighted sound pressure level is approximately 40 dB.

Beta Coefficient Analysis

A type of statistical regression analysis used in situations that have multiple independent variables and a single dependent variable. The analysis is used to compare the relative strength of the effect of each independent variable considered in the analysis. The analysis computes a value of a beta coefficient for each independent variable. The higher the absolute value of an independent variable's beta coefficient, the stronger the effect of that independent variable.

Broadband Noise

Sound that has energy present over a wide range of frequencies.

C-weighting

Frequency-dependent weighting system that is used to correct measured or calculated sound to approximate the human hearing system's sensitivity to different frequencies when the unweighted sound pressure level is approximately 100 dB. C-weighting does not modify lower frequencies as much as A-weighting and is therefore sometimes used when the sound has substantial low frequency content.

Continuous Noise

Noise with negligibly small fluctuations of sound pressure level (SPL) within a specified period of observation.

Dose

The amount of actual noise exposure to which a person is subjected. This term is often used in the context of dose-response relationships and can be measured using various metrics.

Equal-Energy Principal/Hypothesis

The assumption that equal amounts of total sound energy will cause the same amount of harm to human recipients of that sound level, regardless of time duration, intermittency, or other qualities of the sound. That is, if a person is exposed to two different sounds with one being louder but having a shorter duration than the other, but both having the same total sound energy, the two will have the same overall effect.

Exposure-Response or Dose-Response

A measurable relationship describing an effect of noise on humans. The relationships input must be the noise level measured using a standard metric. The response can be any effect of noise on humans, including any of the adverse effects described in this report.

Fast Response

A time weighting that is used to integrate continuous measurements to reduce the temporal variation. A fast response applies an exponential window to the incoming data with a time constant of $\tau = 125$ milliseconds. The output of this time weighting can still be a continuous signal (if applied using analog circuitry). Other time weightings include impulse ($\tau = 35$ ms) and slow ($\tau = 1$ s). Of these three, the fast time weighting most closely approximates the human auditory systems time integration. Fast response noise measurements are usually notated in noise metric abbreviations with a subscripted "F," for example, L_{AFmax} .

Frequency

The physical characteristic that describes the number of repetitions per second of a sound in units of Hertz (Hz).

L_{dn}

Day-night average sound level. Calculated by averaging sound levels throughout a 24-hour period, with a 10 dB penalty added to nighttime noise levels. A-weighted metric. Also depicted as DNL.

L_{day}

The average, A-weighted sound level, with no penalties added, during daytime hours. Usually between 7 am and 10 pm.

L_{night}

The average, A-weighted sound level, with no penalties added, during nighttime hours. Usually between 10 pm and 7 am.

$L_{evening}$

The average, A-weighted sound level, with no penalties added, during evening hours. Usually between 7 pm and 10 pm.

$L_{Aeq(T)}$

Equivalent Continuous Sound Level. The average, A-weighted sound level over the time T. This value is equivalent to the continuous constant sound level that has the same total energy as the measured sound over the same defined period. Usually, the time T is 1 hour, 8 hours, 16 hours, 24 hours, or another period that is relevant to daily human activities.

L_{max}

Maximum sound level. The maximum time-weighted sound pressure level within a specified time response using, e.g. slow or fast response time.

L_{den}

Community Noise Level or Day-Evening Night Sound Level. 24-hour average sound level with 5 dB penalty applied for evening hours (7 pm to 10 pm), and 10 dB penalty applied to nighttime hours (10 pm to 7 am), with no penalty applied to daytime sound levels. Calculated similarly to L_{dn} or DNL. L_{den} is the metric used in California.

L_{peak}

The peak sound pressure measured within a specified time interval.

Noise-induced Permanent Threshold Shift (NIPTS)

Permanent damage to hearing from noise, most often due to damage of the hair cells inside the cochlea that translate acoustic vibrations into electrical signals transmitted by auditory nerves. Caused by over-exposure to noise, and in turn over-excitation of these hair cells. Permanent threshold shift is a medical condition with multiple negative impacts.

Noise-induced Temporary Threshold Shift (TTS)

TTS is a change in hearing threshold that recovers to pre-exposure levels (baseline) over time. The amount of time to recover to baseline may be relatively fast (minutes to hours) or slow (days to weeks). The TTS hypothesis suggests that TTS measured 2 minutes after 8-hour exposure to a certain level of noise is similar to the NIPTS caused after 10 to 20 years of exposure to the same level of noise.

Pitch

The perceived quality of a sound as it relates to high or low frequencies. In other words, the degree of highness or lowness of a tone.

Slow Response

A time weighting that is used to integrate continuous measurements to reduce the temporal variation. A slow response applies an exponential window to the incoming data with a time constant of $\tau = 1$ second. The output of this time weighting can still be a continuous signal (if applied using analog circuitry). Other time weightings include impulse ($\tau = 35$ ms) and fast ($\tau = 35$ ms). The historical purpose for using a slow time weighting was to slow the needle on analog meters down enough to be read by the technician. Of the three weightings mentioned, the slow time weighting will also

produce the lowest sound level results. Slow response noise measurements are usually notated in noise metric abbreviations with a subscripted "S," for example, L_{ASmax} .

Sound Exposure Level (SEL)

The sound level that has the same total sound energy in one second as a measured sound over a certain period. This is often used when measuring or describing single airplane flyovers or vehicle pass-bys because these events have easily definable start and end times. In these cases, the sound exposure level describes the total sound energy in a noise-generating event normalized to 1 second of time.

Sound Pressure Level (SPL)

The basic measure of sound as it relates to the reference sound pressure. Measured in decibels, it is calculated as 20 times the base 10 logarithm of the ratio of the sound pressure to the reference sound pressure of 20 micropascals.

Spectrum

A description of the multiple frequency components and their respective amplitudes that additively make up a full sound wave.

Tone

In contrast to broadband noise, a sound that has energy content at only discrete frequencies. Pure tones have a single component, complex tones have several components, often with frequencies at integer multiples of the lowest component's frequency.

Wavelength

The physical distance between two peaks in a sound wave. Wavelength is equal to the speed of sound divided by the frequency of the sound. For example at standard atmospheric

conditions, the speed of sound is approximately 1,125 ft/s. Thus, the sound of a pure tone at 1000 Hz would have a wavelength of 1.125 ft.

1 Introduction

The Environmental Protection Agency (EPA) *Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety* (published in 1974 and herein called the Levels Document) and companion works also published in the 1970s (see next section) is foundational for the federal government’s noise policies. The Levels Document considered multiple noise metrics, sources, adverse effects, and levels to protect public health and welfare.

This document synthesizes findings from major publications on noise and its impacts to public health and welfare on selected subject matter. The primary goal of the current research documented herein was to understand which elements of the Levels Document are still applicable today. Specifically, the Volpe Center identified research that either confirms, modifies, or replaces findings in the original document, or identified research that fills in gaps that were not included in the original document.

1.1 Background on the Levels Document

The Noise Control Act of 1972 established two related requirements to publish scientific information about the health and welfare effects of noise. In 1973, EPA published *Public Health and Welfare Criteria for Noise*. In 1974, EPA published the Levels Document. In 1978, EPA published a companion, *Protective Noise Levels: Condensed Version of EPA Levels Document*, which was intended to clarify the original 242-page document in a less technical, 25-page summary focused on the best-understood effects of noise on people.

The Levels Document provided information on the:

- maximum noise exposure levels to avoid significant adverse effects to hearing and activity interference,¹ which were well understood at the time of study,
- effects of special types of noises that were not as well understood at the time of the study, including infrasound, ultrasound, and impulse noise such as sonic boom,
- measurement of environmental noise exposure and “protective” levels of environmental noise in defined areas (i.e., indoor and outdoor land uses) that are requisite to protect the public health and welfare with an adequate margin of safety in terms of hearing loss and activity interference.

A summary of noise levels identified by the EPA as requisite to protect public health and welfare with an adequate margin of safety is provided in the Levels Document and presented below.

¹ The Levels Document described activity interference and annoyance in the same section, as interference affects annoyance. However, the document also notes that annoyance due to other factors (background level, state of the human auditor, etc.) is complex and focus of “levels” was placed more on speech interference as a cause of annoyance than these other factors.

Table 1 Summary of Noise Levels Identified as Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety in 1974 Levels Document

Effect	Level*	Area
Hearing Loss	$L_{Aeq(24)} \leq 70$ dB	All areas
Outdoor activity interference and annoyance	$L_{dn} \leq 55$ dB	Outdoors in residential areas and farms and other outdoor areas where people spend widely varying amounts of time and other places in which quiet is a basis for use.
	$L_{Aeq(24)} \leq 55$ dB	Outdoor areas where people spend limited amounts of time, such as school yards, playgrounds, etc.
Indoor activity interference and annoyance	$L_{dn} \leq 45$ dB	Indoor residential areas
	$L_{Aeq(24)} \leq 45$ dB	Other indoor areas with human activities such as schools, etc.

* Note: The Levels Document uses the notation L_{eq} for long-term equivalent A-weighted sound level. This table uses the notation L_{Aeq} instead of L_{eq} to clarify the use of A-weighting.

Protective levels were not intended to be noise limit criteria; rather they were intended to be a basis for setting standards along with other relevant factors including technical feasibility and economic reasonableness. The 1978 Condensed Version of the EPA Levels Document clarified, “they must not be viewed as standards, criteria, regulations, or goals. Rather, they should be viewed as levels below which there is no reason to suspect that the general population will be at risk from any of the identified effects of noise.”

1.2 Introduction to Noise

Noise is defined broadly as unwanted or undesirable sound. Sound is vibration in a fluid medium, usually air. When scientists study this phenomenon in humans, they usually refer specifically to vibrations with frequencies between 20 Hz and 20,000 Hz (or 20 kilohertz), the frequency range that can be heard by humans. Whether a sound is categorized as noise or not is subjective and depends on the listener and the context. Sound generally becomes unwanted because it produces a negative psychological or physiological response in humans. Usually these sounds are byproducts of human activities that are heard and experienced by uninvolved surrounding populations.

Noise is most easily analyzed within the “source, path, receiver” framework, illustrated in Figure 1. This framework asks the following three questions:

- 1) How is the sound produced?

This is the **SOURCE** of the sound, and can be transportation noise like from a highway or a moving train or plane. Other sound sources are stationary like factories or quarries. The source of the sound also determines the physical properties of the sound that eventually influence how it affects the receiver.

2) How does the sound travel from the source to the receiver?

This is the **PATH** of the sound. The path may be completely unobstructed through the air. Often, there are solid objects the sound reaches before reaching the receiver. This can be an earthen hill, a sound barrier, or the wall of a home. Sound can travel through some of these barriers. Windows are a good example that attenuate the sound somewhat, but still allow some sound waves to travel to the interior of a home. In other cases, the sound may travel around these obstacles. The ability to travel through or around the obstacles depends on the properties of the sound and the properties of the obstacle, e.g., how large and heavy it is.

3) Who or what experiences the sound?

This is the **RECEIVER** of the sound. This includes the human who can hear the sound and the auditory system that allows them to hear it. Sometimes, the entire structure, like the residence, workplace, or school building, is used as an ersatz receiver of the sound.

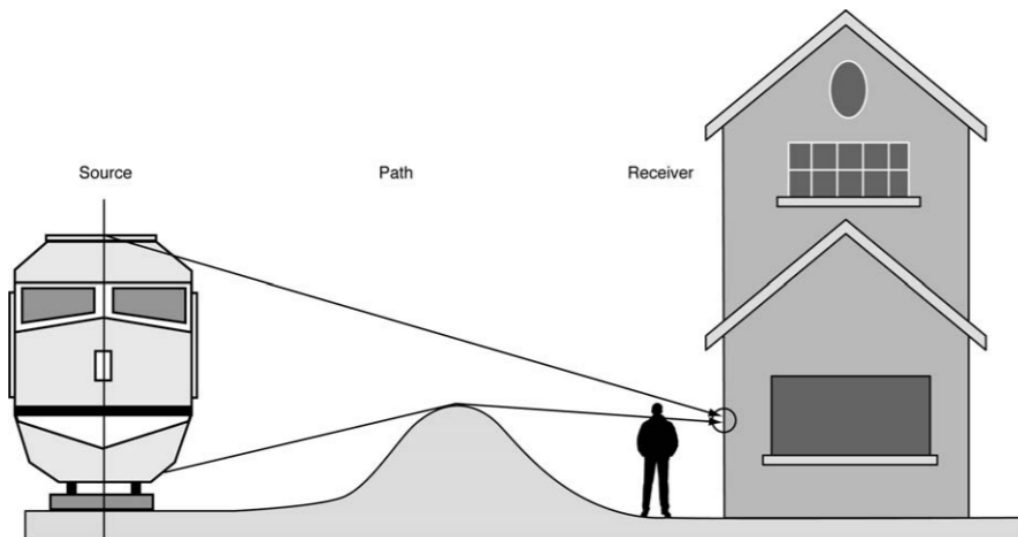


Figure 1 Source-Path-Receiver Framework (Source: FTA Noise and Vibration Impact Assessment Manual)

Sound can be studied separately at each of these three physical locations. Attenuation techniques are different in each case, and the sound itself may have different characteristics at the source, over the path, and at the receiver. It is important to understand how the: 1) sound is created and its properties at the point of creation; 2) sound may be reflected or absorbed while traversing the path; and 3) receiver reacts to the resulting sound.

1.2.1 Physical Properties of Noise at the Sound Source

Sound is a variation in the pressure of the air from normal atmospheric pressure. The variations are usually produced by the physical vibration of a solid object. The vibration of an object moves the air particles surrounding that object back and forth. The air around the object thus alternates between high and low pressure relative to atmospheric pressure. This alternating pattern propagates as a pressure

wave through the air, and can travel far distances if it is not attenuated or reflected by another solid object. At normal atmospheric temperature and pressure, sound travels at a constant speed just over 1,000 feet per second.

Two important numerical values are used to describe the physical properties of the sound pressure wave. The first is **amplitude**. The amplitude of the wave is the size of the difference between the maximum pressure of the air in the sound wave and the regular atmospheric pressure of the air without a sound wave traveling through it. The larger the pressure variations, the larger the amplitude, and the louder it will be when experienced by the receiver. Amplitude can be described simply using the pressure metric Pascals. The human hearing system cannot detect pressure variations smaller than 20 micropascals. Therefore, sound waves below this absolute amplitude cannot be heard by humans. Additionally, the range of the amplitude of commonly occurring sound waves in nature and human society is very large; the loudest of these common sounds can be up to 200 Pascals, or 10 million times more pressure than the quietest sound that can be heard. Because of the absolute lower limit of the human hearing system and the large range of values for pressure differential, the amplitude of sound is often described using decibels, which typically describes the sound pressure logarithmically relative to 20 micropascals. Some common sounds and their approximate sound levels are shown in Figure 2 to the right.

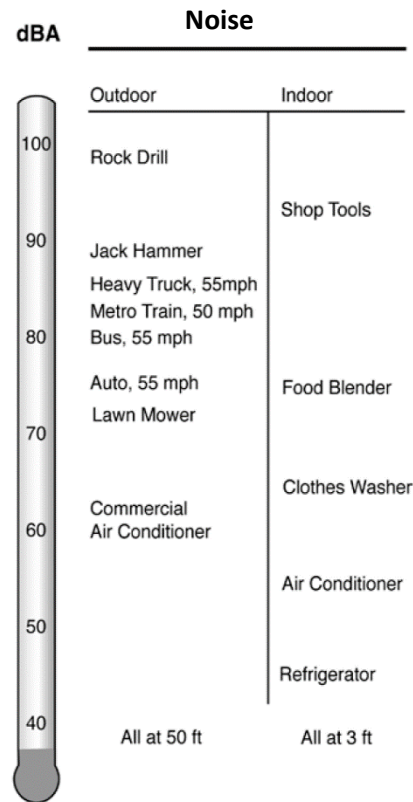


Figure 2. Sound levels from a variety of indoor and outdoor sources.

The second important property is **frequency**. The frequency of the sound describes how quickly the pressure variations in the wave go from high pressure to low pressure and back again. The faster the variations occur, the higher the frequency will be. The frequency of the sound determines the pitch of the sound as experienced by receivers. Thus, the higher the frequency, the higher the pitch that will be heard. The variation from high to low pressures in a sound wave in air happens many times per second. Therefore, frequencies are generally described using the metric “Hertz,” which means “cycles per second.”

Another important physical quality of sound is the **duration**. Sounds can be continuous and last for many hours, like the steady hum of a refrigerator in a household or the sound of cars on a busy highway near an urban area. Other sounds can last for minutes like construction equipment. Some sounds are impulsive; they last for very short amounts of time, often less than a second, and only include a small number of pressure variations, such as an explosion. Closely related to duration is the pattern of the sound. If it is not continuous, sounds may happen at a regular interval over the course of the day, or intermittently at certain times a day, or for a few hours randomly. It may cease completely during

nighttime hours or continue through the night. Each of these qualities can have different effects once the sound reaches the relevant receiver.

While sound waves can have a regular pattern of high and low pressures with a constant frequency and amplitude (pure tone), almost all sounds contain a combination of different frequencies at different amplitudes that change the quality of the sound. Sometimes, there is a broad range of densely spaced frequency components at similar amplitudes. Sound that includes wide ranges of high and low frequencies at similar amplitudes is called “broadband” noise. Physical actions that create broadband noise include tires rolling on pavement, wind and rain, air conditioning and heating systems in buildings, and some engine noises.

Sounds can have “tones” or components at discrete frequencies that have much higher amplitudes than neighboring frequencies. A single tonal component is called a “pure-tone”. Multiple tonal components are called a “complex tone”. Sirens on police cars or ambulances create tones that change over time in a regular pattern. Many gasoline engines produce broadband noise that has some tonal content due to the periodic rotations of the components within them.

1.2.2 Sound Attenuation over the Path

Sound waves lose amplitude as they move further from the sound source. The most important reason for this attenuation is that sound energy is spread out over a larger volume of air at larger distances from the origin point of the sound. For point sources, this spreading translates to about a 6-decibel reduction every time the distance doubles. When the source of the sound is a line instead of a singular point, the sound energy spreads more slowly. This means the sound reduces by 3 decibels every doubling of distance.

Further attenuation is caused by sound absorption as the wave travels through the atmosphere. This phenomenon has to do with the complex interactions that occur between the gaseous molecules that make up the air, and includes energy dissipation from friction and mechanical movements of the gas particles. Humidity, temperature, pressure, and the mix of different gasses in the air all affect the rate of atmospheric absorption. The frequency of the sound also affects the rate of attenuation by absorption. The attenuation can range from .03 decibels to 60 decibels for every 1,000 feet depending on the frequency and the atmospheric conditions.

Absorption can also be caused by human made objects through which the sound travels. The method of energy dissipation usually utilizes friction to convert the acoustic energy into thermal energy. Examples include constrained layer damping, where a viscous layer between two metal plates converts the vibrations of the plates to heat; and the heating of air by pumping the air through constricted channels in open-cell foam insulation. Sound absorbing materials are often designed to reduce the amplitude of sound waves that impinge upon them. When designed adequately, attenuations of the overall sound levels may be approximately 25 decibels from one side of the sound absorbing barrier to the other, depending on the material and geometry of the site where the insulation is installed.

Environmental shielding, like earthen hills, sound barriers, and buildings block sound waves from directly propagating to receiving sites. This is called “shielding,” and it is an important consideration in assessing environmental noise levels produced by any source. Despite shielding effects, the sound is not

usually fully blocked from reaching receivers. Diffraction allows part of the sound wave to “roll-over” the barrier. The effectiveness of the shielding depends on the frequency of the sound and the geometry of the object providing the shielding.

Finally, ground surfaces also reflect and attenuate sound waves. In addition to the sound waves that directly reach the receiver, additional waves reach the receiver after reflecting off ground surfaces. These reflected waves tend to increase the overall noise levels experienced by the receiver. However, reflected waves will have lower amplitudes than the waves that travel directly from the source to the receiver, because the ground absorbs some of the sound energy as the wave is being reflected. The amount of energy that the ground absorbs, and thus the degree to which the reflected wave is attenuated, changes based on the type of ground over which the sound wave travels. For example, hard pavement or concrete reflects sound well, and there is little attenuation of the reflected wave once it reaches the receiver. Grassy or vegetated ground surfaces absorb sound energy more readily, so the reflected wave is more attenuated when it reaches the receiver. The final sound experienced by the receiver is a combination of direct and reflected waves, as illustrated in Figure 3.

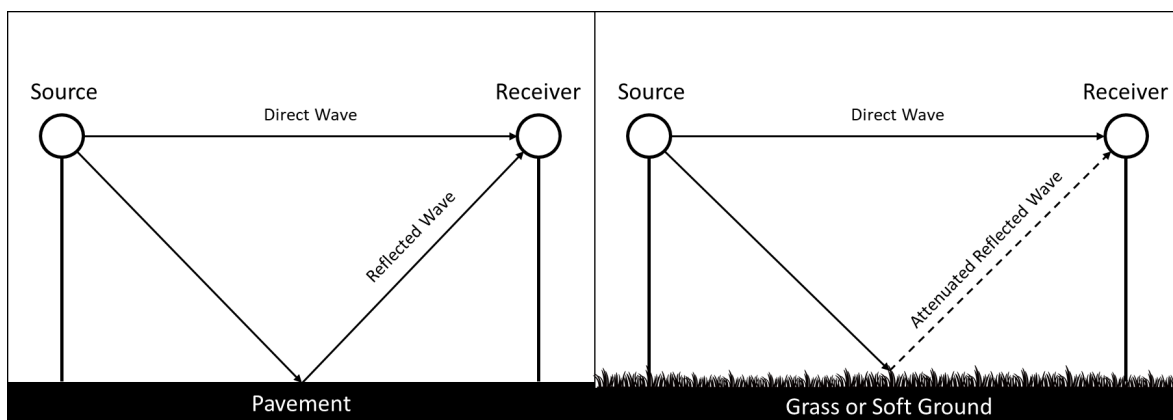


Figure 3. Reflected waves and ground absorption over hard and soft ground surfaces

1.2.3 Effects of Sound on Humans

Humans are sensitive to all the physical qualities of sound discussed previously. As discussed, the higher the amplitude of a sound, the louder and easier it will be to hear by humans. Humans are also more sensitive to components in the frequency range between 1,000 and 5,000 Hertz than outside this range. Therefore, the way a sound is perceived will depend on the level, frequency, duration, and other qualities of the sound. Extremely high amplitudes in the frequency range where humans are sensitive may cause pain or permanent damage to the human hearing system.

Objective metrics have been developed that describe sound relative to how humans experience it. These include frequency-weighting factors to describe how humans experience sounds at different frequencies and includes referencing sounds to a minimum audible threshold rather than using an absolute scale. Noise metrics are reported in decibels, which makes analysis easier within the large range of sound pressures humans can hear. See the glossary for more information about metrics and other subject-specific terms.

The most important metrics used in this report are summarized in Table 2 below. Note that most of these metrics average the sound energy in an environment over a period. The study of environmental noise often seeks to obtain a holistic view of both noise and how it might affect living things in an area. Therefore, averaging metrics are most frequently used.

Table 2. Noise Metrics Used Frequently in this Report

Metric	Description
$L_{Aeq(T)}$	The A-weighted average sound level over the time T. This value is equivalent to the continuous constant sound level that has the same amount of energy as the measured sound over a defined period. Usually, the time T is 1 hour, 8 hours, 16 hours, 24 hours, or another period that is relevant to daily human activities.
L_{dn}	Day-night average sound level (Also shown as DNL). This metric is a 24-hour average of sound levels over the course of the entire day, with a 10 dB weighting added on to sound levels at nighttime hours, usually between 10 pm and 7 am. This is the basic unit of measure for most federal agencies.
L_{day}	The average sound level, with no weighting added, during daytime hours. Usually between 7 am and 10 pm.
L_{night}	The average sound level, with no weighting added, during nighttime hours. Usually between 10 pm and 7 am.
L_{peak}	The peak sound pressure measured within a specified time interval.
L_{max}	Maximum sound level. The maximum time-weighted sound pressure level within a specified time measured using slow or fast response time.

2 Analysis of Adverse Effects

There is a complex relationship between noise exposure and possible adverse effects. Noise exposure can vary by level, frequency, duration, and other acoustic characteristics. Human response to noise can vary not only due to the noise exposure itself, but also due to cognitive processes. The ultimate impact can present itself in many forms ranging from a feeling of discomfort (affecting many) to disease and death (affecting relatively few), as presented in Figure 4.

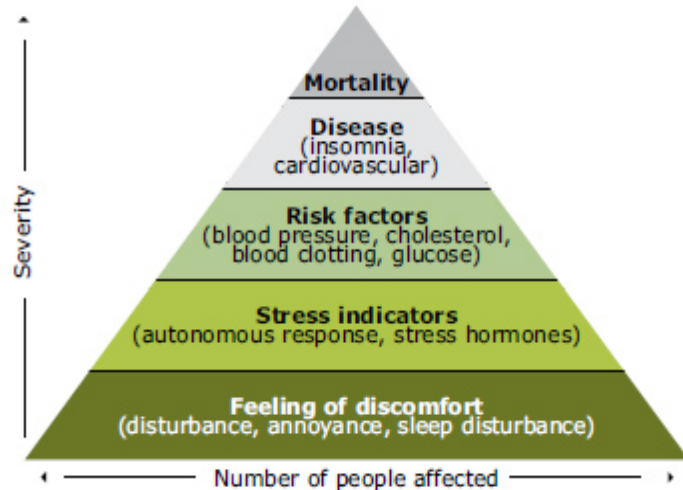


Figure 4 Pyramid of Noise Effects (Source: European Commission, adapted from Babisch 2002, based on WHO, 1972).

Figure 5 depicts the relationship among some adverse effects to noise in terms of direct (physical, or objective noise exposure) and indirect (emotional and cognitive, or subjective perception) pathways (Munzel et al. 2014). The figure demonstrates how noise may contribute to severe impacts through activity interference, annoyance, and sleep disturbance. Chronic exposure to excessive noise and the morbidities it facilitates can be fatal.

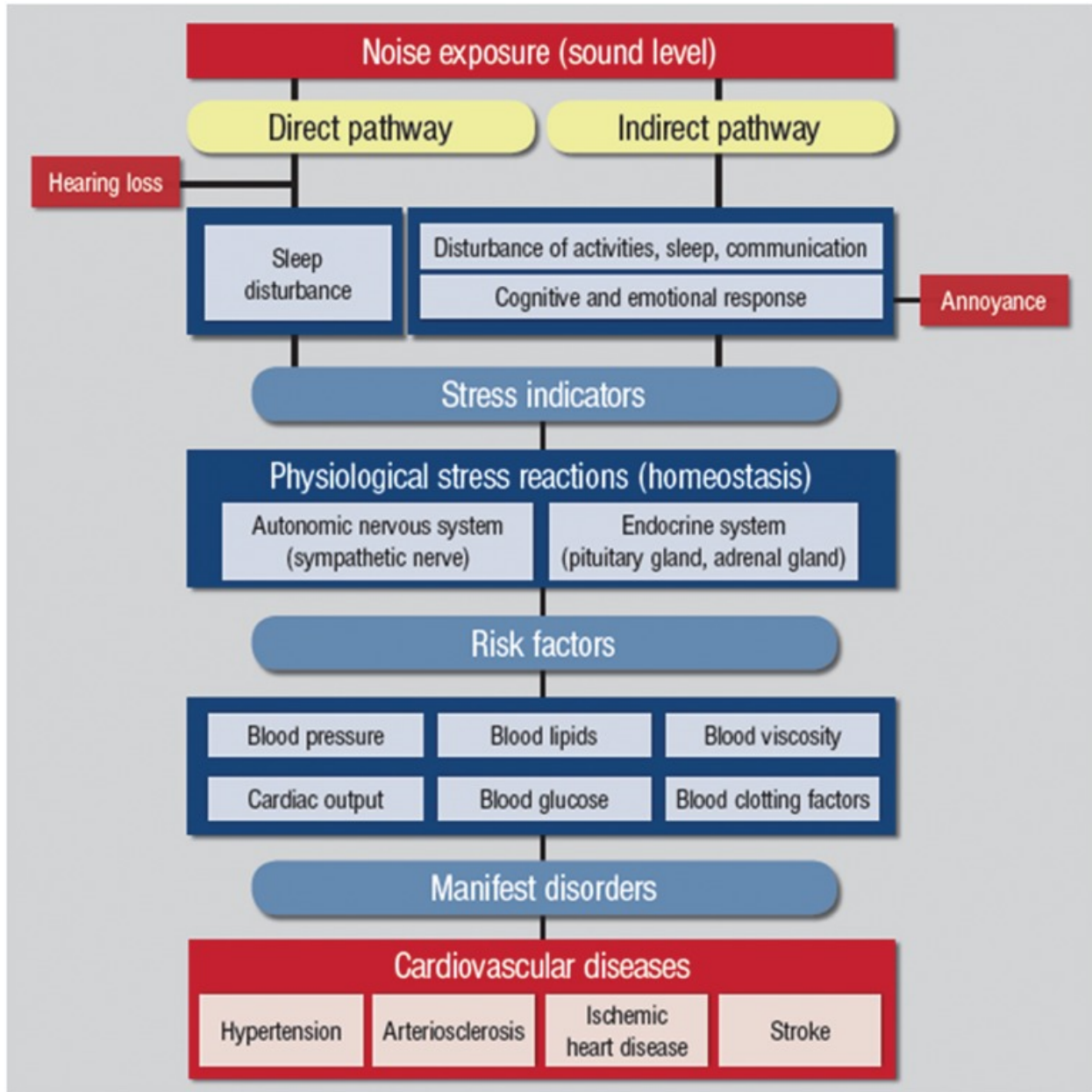


Figure 5 Noise effects reaction scheme (Source Munzel et al. 2014, adapted from Babisch 2002).

This section of the document describes the following adverse effects: hearing loss, activity interference, annoyance, cognitive effects, health and sleep impacts, and financial impacts. Each adverse effect includes subsections that provide:

- A summary on how the Levels Document addressed the topic;
- Findings in research literature that validate or change the information provided in the Levels Document; and
- If applicable, gaps in knowledge on the topic.

2.1 Hearing Loss

Hearing loss due to noise exposure is the shift in noise level threshold at which a person can hear a sound. Exposure to loud continuous, intermittent, and impulsive noises can cause different kinds of hearing loss at different rates. Cross sectional studies as well as medical and biological research from the early 1940s to the present have helped to solidify the understanding of how noise-induced hearing loss (NIHL) occurs, how it can be prevented, and the levels of environmental noise that cause this phenomenon.

2.1.1 How the Levels Document Addressed Hearing Loss

The discussion on hearing loss in the Levels Document began with a list of assumptions and considerations the authors made in order to propose a level of environmental noise to protect against hearing loss. These included:

- 1) Hearing shifts to non-noise exposed populations are caused by aging and other sources of deterioration rather than noise exposure.
- 2) Noise levels below hearing threshold levels cannot cause more hearing loss. For example, if a person can only hear sound at or above 70 dB, they will not experience more hearing loss from exposure to levels of noise below 70 dB.

The authors went on to discuss that hearing loss is often experienced first in the range of frequencies surrounding 4 kHz, which is important for speech intelligibility. These factors are used to justify the focus of recommended levels around 4 kHz. The remainder of this discussion refers only to noise at the frequency of 4 kHz on which the Levels Document focused its analysis. Additionally, the Levels Document specified that, while it is desirable to prevent any level of hearing loss from noise exposure, hearing loss is only measurable down to a 5 dB threshold shift, as any shift below this is almost unnoticeable to subjects. Therefore, the recommended environmental noise levels would be aimed at protecting against 5 dB of threshold shift.

The Levels Document used data mainly from two studies in its analysis of hearing loss. One is a public health survey conducted in the early 1960s that reported the hearing threshold levels of adults organized by age range and sex. The other study was an Air Force paper on justifications for noise exposure limitations published in 1973. The study presented summary data of predicted noise-induced permanent threshold shifts (NIPTS) at certain frequency ranges. The predictions were obtained by averaging results from a few different prediction methodologies found in a few important hearing loss studies from the 1960s and 1970s.

While the 1960s public health study provided data based on age and sex, the Levels Document's analysis required comparisons between a non-noise exposed and a noise exposed group of subjects. In order to obtain these subject groups, the authors assumed that differences in hearing threshold levels between men and women in the 55 to 64 year age range are due to differences in noise exposure levels over 40 years. The authors justified this assumption by citing there was minimal evidence of any physiological reasons why hearing levels would be different between men and women in this age range. Thus, the Levels Document uses this group of female subjects as the "non-noise exposed group" and the male subject as the noise exposed group in the remainder of its analysis.

To derive recommendations for noise levels, the Levels Document extrapolated the data from both of the above-mentioned research studies. From the Air Force study, the Levels Document derived a curve that related the 40-year noise exposure levels for 8 hours a day to the percentile of the population that may experience 5 dB of NIPTS. Additionally, the Levels Document derived a curve from data presented in the public health survey that showed the percentage of the population with hearing thresholds above certain noise levels for the apparently non-noise exposed group (55-64 year old women). They termed this curve the “PHS” curve, after the public health survey from which the data were obtained. The combined graph showing these two curves is shown in Figure 6.

To reiterate, curve 1, labeled “5 dB NIPTS AT 4000 Hz” in the figure, gives the 40 year exposure level that is necessary to cause 5 dB NIPTS at a certain percentile of the population. For example, at an exposure of about 75 dB, 20 percent of the population will have at least a 5 dB shift. Reading the rightmost part of the graph, with a 40-year exposure to 67 dB, only 1 percent of the population will have at least a 5 dB shift. Curve 2, labelled “PHS – 4000 Hz” in the figure, gives the hearing threshold levels by percentile, from best hearing to worst hearing, in the apparently non-noise exposed group. For example, 10 percent of “non-noise exposed” group is expected to have hearing threshold levels of at least about 61 dB, while 5 percent of the population is expected to have hearing threshold levels of 71 dB. The horizontal axis represents the percentile of the population distributed by noise induced threshold shift at certain noise levels from smallest shift to largest shift for curve 1, and by hearing threshold level for curve 2.

It is important to recognize that “hearing threshold level” and “noise induced threshold shift” are not necessarily numerically related concepts, even though the two are illustrated on the same graph in the Levels Document. NIPTS is a threshold shift that is caused by noise exposure. Hearing threshold is simply the level a sound must be for a person to hear it. The assumption used in the Levels Document’s analysis is that the apparently non-noise exposed group show differences in hearing thresholds due mostly to aging², and that any noise induced threshold shift they have experienced is negligible. Therefore, the hearing thresholds of this group represent average amounts of hearing loss experienced by people aged 55 to 64 that would occur without any exposure to excess noise.

The Levels Document explained that, since noise below a person’s hearing threshold cannot cause hearing damage according to previously explained assumptions, the 5 dB NIPTS curve could not cross the PHS Curve. In other words, because the apparently non-noise exposed group cannot hear below the levels given by curve 2 in the figure, exposure to noise below those levels cannot cause damage to their hearing. The authors termed the point where these two curves intersect the “critical percentile.” The 40-year exposure level at this critical point is about 73 dB. Thus, 40 year exposure levels below 73 dB will not cause any more than 5 dB of threshold shift in the apparently non-noise exposed population. The conclusion was that a reasonable estimate for recommended 40 year, 8 hour workday exposure limits should be 73 dB.

² Hearing loss due to aging is called *Presbycusis*. It is caused by the normal aging process of the auditory system, and is experienced at different rates and at different ages by different people.

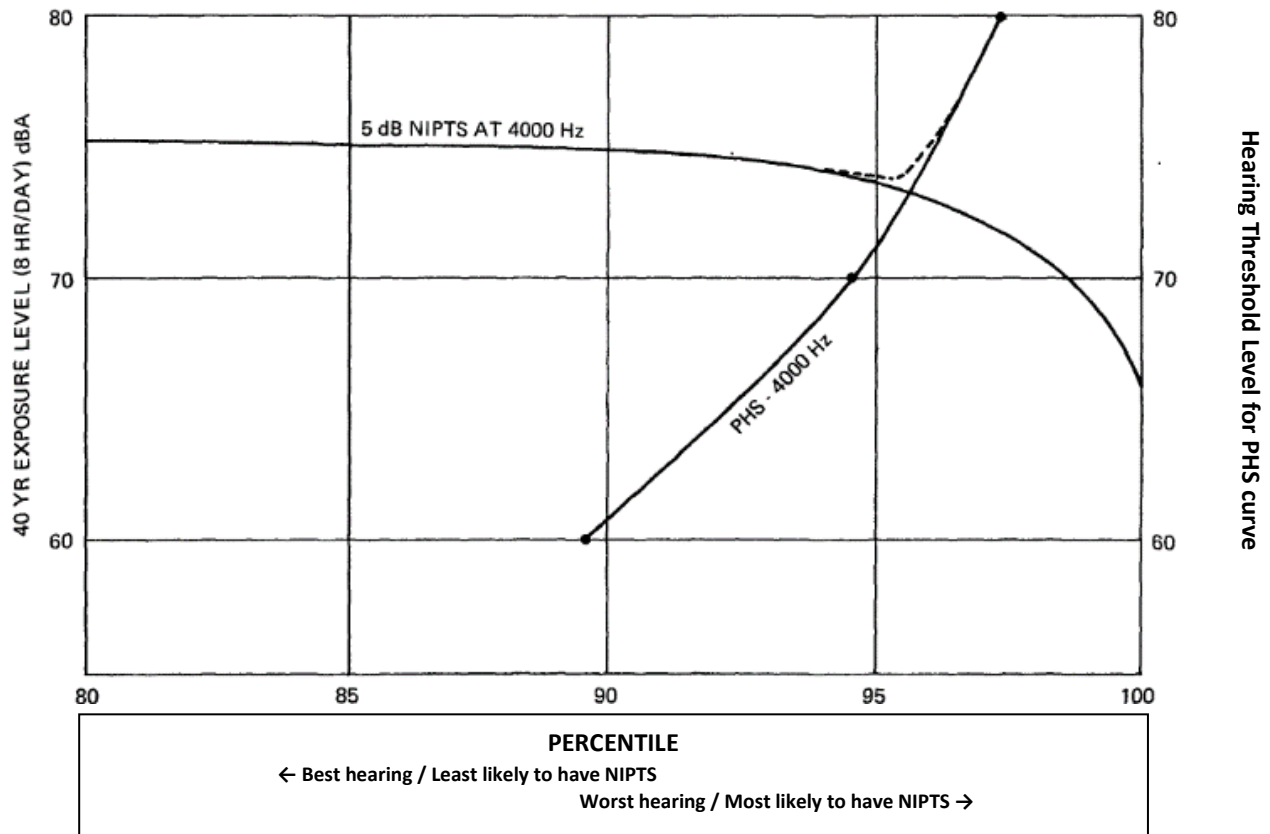


Figure 6 Derived relationships showing 1) percentile of population with 5 dB NIPTS at 4000 Hz with 40-year noise exposure levels and 2) percentile of population with different hearing threshold levels

Additional discussion is provided to account for exposure to intermittent noise and impulsive noise. These analyses mostly involve adjustments using the equal energy principal.³ An additional hypothesis is used in addition to the equal energy principal, called the temporary threshold shift hypothesis. This states that temporary threshold shifts measured 2 minutes after 8-hour exposure to a certain level of noise is similar to the NIPTS caused after 10 to 20 years of exposure to the same level of noise.

Using the above-mentioned hypotheses, the authors estimated a correction factor of 5 dB for intermittent noise experienced over an 8-hour workday. The Levels Document provided additional correction factors based on the same hypotheses to account for adjustments from a 250-day work year to 365 days of exposure, as well as from an 8-hour workday to a 24-hour day. The adjustments used to obtain the final recommended level are shown in Table 3.

³ The equal energy principal states that equal amounts of aggregate sound energy will cause the same amount of measurable damage to the human hearing system, regardless of time duration, intermittency, or other qualities of the sound. That is, if a person is exposed to two different sounds with one being louder but having a shorter duration than the other, but both having the same total sound energy, the two will cause the same damage.

Table 3. Recommended level corrections for intermittency and exposure durations used by the authors of the Levels Document

Noise Level	Correction	Description
73 dB L_{Aeq8hr}	0 dB	Original 8 hour, continuous noise level limit obtained from analysis of data from Public Health Survey and Air Force Report (Critical Percentile analysis)
78 dB L_{Aeq8hr}	+5 dB	Adjustment for intermittency during an 8-hour workday. Obtained by adjusting the equal energy curve to better fit data on temporary threshold shift from intermittent noise level exposure.
76.4 L_{Aeq8hr}	-1.6 dB	Adjustment to account for 365 days of exposure instead of 250 working days per year. Obtained using the equal energy principle.
71.4 $L_{Aeq24hr}$	-5 dB	Reverse adjustment from intermittent noise limit to continuous limit for 24 hours per day, 365 days per year.
70 $L_{Aeq24hr}$	Rounding	Considering assumptions, other sources of uncertainty, and a desire to be conservative, the Levels Document rounded down to 70 dB from 71.4.

The final noise level given by the Levels Document is rounded down to 70 dB for a conservative estimate, considering uncertainties in the original occupational exposure limit analysis and the correction analysis. The uncertainties discussed in the Levels Document include that the various studies used in the analyses do not have comparable study populations, and therefore their results may not be comparable. Additionally, permanent threshold shift may not be noise-induced. There is evidence that other factors may cause threshold shifts; it is difficult to prove that shifts are caused by noise exposure without detailed understanding of a subject's noise exposure history, which is often unavailable or vague. Extrapolations of data were also used extensively in the Levels Document analyses, which introduced inherent inaccuracies and uncertainties in the results.

One noticeable source of uncertainty is the assumption that female study subjects were not exposed to similar noise levels as the male group. Using the data from the female group as a representation of a non-noise exposed population presents some inherent uncertainties. While it might be valid to assume that, in the 1960s when the pertinent studies were performed, women were less likely to be exposed to loud occupational noise than men were, it is difficult to justify the assumption that women were not exposed to noise at all. The authors of the Levels Document did not have access to better data on non-noise exposed populations and therefore used the population assumed to be the least exposed from the sources available. The authors admitted that these assumptions introduced uncertainties and inaccuracies in the resulting analysis. The next section discusses how different analyses of the same studies provided a more nuanced understanding of threshold shifts without including the same assumptions as were included in the Levels Document analysis.

2.1.2 Current Understanding of Noise-Induced Hearing Loss

This section describes 1) data from NIPTS studies used to inform 2) analyses for the Levels Document and International Standards Organization, and 3) resulting predictive levels various agencies recommend or require to protect against noise-induced hearing loss.

2.1.2.1 Data: NIPTS Studies from the 1960s and 1970s

The basic understanding of the noise levels that cause permanent degeneration of hearing ability has not changed substantially since the Levels Document was published. In fact, different regularly updated international standards, recommendations, and regulations on occupational noise continue to utilize the same databases of hearing level data used by the Levels Document. The vast majority of the data used comes from studies performed in the 1960s and 70s (Kowalska, Zabarowski, 2017). These databases are summarized in synthesis studies published by three prominent researchers at the time: Passchier-Vermeer in 1968, Robinson in 1968 and Baughn in 1973. The results of these syntheses were summarized and presented in 1973, partially in support of the writing of the Levels Document, by Daniel L. Johnson, a Major in the United States Air Force (Johnson, 1973). In 1977, both Passchier-Vermeer and Robinson published updated syntheses of hearing loss databases with a larger focus on predicting NIPTS from occupational noise exposure. Based on different analysis procedures of similar databases used in the original syntheses, Passchier-Vermeer's and Robinson's second reports were summarized again by Johnson in a 1978 summary in support of the development of international standards on noise induced hearing loss (Johnson, 1978).

The syntheses of hearing loss data by Passchier-Vermeer, Robinson, and Baughn are aggregations of data from cross-sectional studies that reported noise induced threshold shifts in adults and children with estimations of their exposure to certain noise levels over certain periods. Results are usually organized into percentile groups ranging from best hearing to worst hearing from the 1st to the 100th percentile. Similar to most other studies on this subject, the three researchers focused on occupational noise exposure rather than environmental or recreational noise exposure. It is easier to make assumptions about subjects' exposure to occupational noise, as people tend to be exposed to these noises every working day for many years. Since the original studies were performed, there have been very few efforts to update or supplement the original data with either cross-sectional or longitudinal studies on noise-induced hearing loss.

2.1.2.2 Analyses: Comparison of International Standards Organization and Levels Document Analyses

One notable and important standard on which many regulations and recommendations are based was published by the International Standards Organization (ISO). Mentioned previously, the ISO standard 1999:2013 utilized Johnson's later report from 1978, along with a few supplemental research reports, to formulate an algorithm for predicting a person's noise-induced hearing loss resulting from a number of years of exposure over 8 hours per work day. Last updated in 2013, these standards continue to be accepted and used by international organizations to estimate risks of hearing loss both in occupational and non-occupational settings. The equations in the standard take into account aging effects, sex, exposure time, and exposure level to determine hearing loss effects.

There is a clear difference between the results presented in Johnson's 1973 report and his 1978 report. Based on evidence available at the time, both Passchier-Vermeer and Robinson made an important assumption in their second, 1977 syntheses. Below 75 dB L_{eq8hr} noise exposure over 40 years, NIPTS was deemed negligible for all percentiles of the population. This essentially anchors the origin of the resulting curve and lowers NIPTS predicted at higher levels of noise exposure. The results tables in Johnson's second report are skewed by 5 to 8 dB from the values shown in his second report due to this

assumption. This difference in results in Johnson’s two reports leads to a marked difference between the predicted levels of NIPTS in the Levels Document and the ISO standard. The curves derived by the Levels Document show about 6 dB more threshold shift than those given in the ISO standard at 75 dB L_{eq8hr} of noise exposure.⁴

Figure 7 shows the estimates of permanent threshold shift predicted by the ISO equations at different exposure levels and different exposure timelines. The axes and parameters represented in Figure 7 are comparable to Figure C-2 in the Levels Document. The values shown in the figure are for the 4000 Hz frequency and are based on 40 years of exposure. As previously described, the ISO standard predicts 0 dB NIPTS from 40 years of exposure to 75 dB L_{eq8hr} for all population percentiles. As a comparison, 40 years of exposure to 80 dB L_{eq8hr} of noise is predicted to cause 8.5 dB NIPTS at the 90th percentile by the Levels Document’s analysis, while the ISO standard predicts 2.25 dB NIPTS.

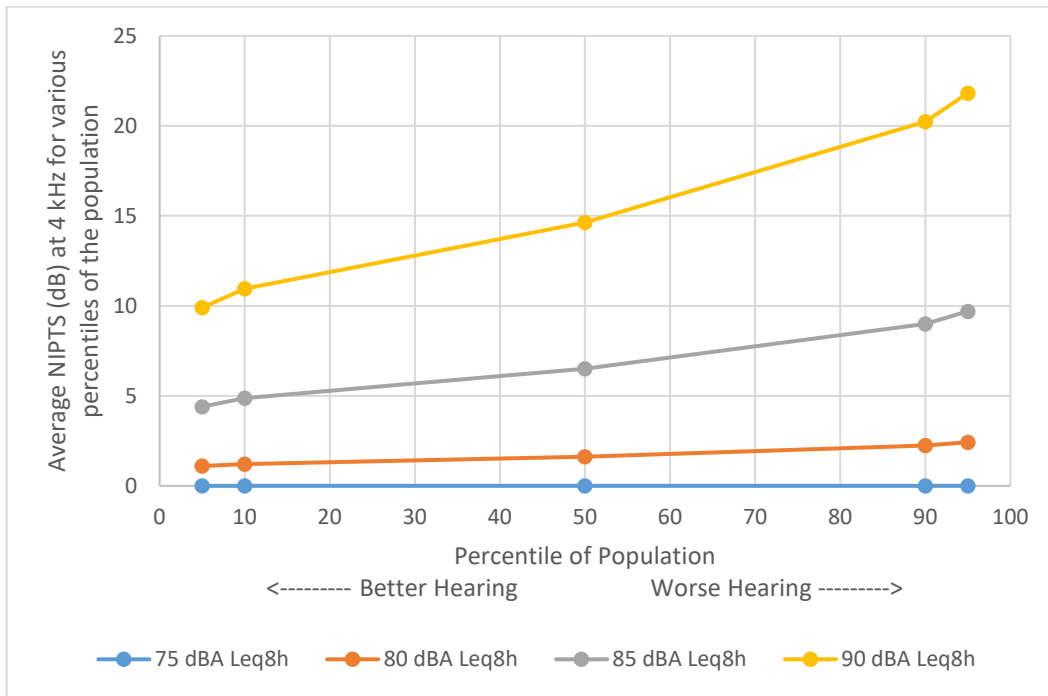


Figure 7. NIPTS Predicted at different 40-year exposure levels and percentiles of the population by the ISO 1999 standard⁵

While the difference between the predicted values of NIPTS in the Levels Document and the ISO standard are primarily due to the differences between results in Johnson’s first and second syntheses, there are a few other notable differences between the analyses in the Level’s Document and the ISO standard. First, the Levels Document extrapolated data from Johnson’s report and the public health

⁴ Johnson does not discuss this difference in his secondary synthesis. In fact, he specifically specifies that Passhier-Vermeer’s results in the second analysis for the most part agree to those in the first analysis. This unexpected gap in discussion makes it difficult to fully understand the differences in NIPTS predicted by Levels and ISO.

⁵ Obtained using “ISO_1999_2013_Calculations” Matlab functions written by Edward Zechmann and Richard Brown. The functions therein are implementations of the equations and algorithms presented in the ISO 1999:2013 standard.

survey to predict NIPTS for higher percentiles than were presented in an effort to protect a higher percentage of the population. Additionally, the databases used in the ISO algorithms are specific to the 50th percentile, using conversions to account for higher percentiles. NIPTS at the higher percentiles shown in Figure 7 were calculated using these conversions. The uncertainty introduced by using these conversions makes it difficult to compare predicted NIPTS between the ISO standard and the Levels Document analysis. The inclusion of the supplemental studies from the 1970s also shift the predicted NIPTS in the ISO standard to slightly lower values than are shown in the Levels Document. Combined with the differences in the two Johnson reports, these additional differences lead to different predictions between the two analyses.

2.1.2.3 Results: Comparison of Protective Noise Level Recommendations or Requirements

The ISO standard, along with individual analyses of the same databases used by Passhler-Vermeer, Robinson, and Baughn, were used by a number of regulatory bodies to publish environmental and occupational noise exposure limits. Standards that use these sources of data include the U.S. Occupational Safety and Health Administration’s (OSHA) occupational noise exposure regulations, the U.K.’s occupational noise control regulations, and the World Health Organization’s occupational noise exposure recommendations. As a comparison, some of these regulations and standards are summarized below in Table 4. The exposure limit provided by the Levels Document is also shown for comparison.

Table 4. Comparison of occupational noise level limit for different organizations.

Standard, Recommendation, or Regulation	Noise Level Limit to Protect Hearing Loss (dB)	Protected Percentile	Frequencies defining hearing loss	Exposure Time
U.S. EPA Levels Document	70 dB	100 th	4 kHz	24 hours
U.S. OSHA Noise Level Limits	90	25 th	2, 3, 4 kHz	8 hours per day limit
U.S. NIOSH ⁶ Occupational Noise Criteria Recommendations	85	50 th	1, 2, 3, 4 kHz	8 hours per day,
U.K. Occupational Noise Regulations	80, 85, 87	50 th	1, 2, 3, 4 kHz	8 hour lower, upper, and limit
WHO Occupational Noise Recommendations	85	50 th	.5, 1, 2, 4 kHz	8 hours per day,

An important note concerning the data shown above is that choosing a noise level to protect against hearing loss is a decision that must take into account socio-economics of the region, typical environmental noise levels, age distributions of the population, and other factors. Most countries have decided that 5 dB of permanent threshold shift is a reasonable baseline against which to protect, and their noise level limits reflect this decision. Additional differences shown in Table 4 are the different

⁶ National Institute of Occupational Health and Safety, an institute of the Centers for Disease Control

frequencies that regulatory and standards making bodies choose to take into account when making their recommendations. An agency's final regulation or standard level also depends on the specific analysis procedures used, even if the source data and studies are the same.

2.1.2.4 Important Remarks Regarding the Purpose of the Levels Document

While the Levels Document's maximum level to protect against hearing loss seems more stringent than many regulations, it is important to note that this was not a regulatory document, and that the levels therein were meant to be informative and not to be considered standards. Appendix F in the Levels Document discusses how the authors interpreted their own responsibility to provide information on safe levels of noise exposure, and how it differed from the responsibilities of other agencies like that of Occupational Safety and Health. Thus, they based their recommended levels on protecting the entire population at any time of day without considering factors such as socioeconomic costs or current environmental noise levels, while these factors must be considered when establishing regulatory standards. Additionally, the analysis in the Levels Document combined hearing level data with threshold shift data from two different studies. This type of analysis differed from analyses used to set regulatory standards, and resulted in lower recommended levels, as justified in Appendix F of the Levels Document. This difference in analysis procedure explains some of the disparity between the Levels Document's recommendations and other standards and regulations.

2.1.3 Contemporary Research Topics

While understanding of noise-induced permanent threshold shift has not changed significantly since the 1970s, there have been some other areas of research interests in the subject of hearing loss. There is consensus in the scientific community that there are two main causes of acquired hearing loss⁷. The most common cause is aging. Hearing ability naturally deteriorates with age, whether or a not a person is exposed to excessive amounts of noise throughout their lifetime. The second most common cause of permanent hearing loss is excessive noise exposure (Caroll, Eichwald, 2017). These two effects are highly interrelated, and there is a gap in the current understanding of these complex relationships. For example, there is some evidence to suggest that early excessive noise exposure increases the risk of hearing degeneration due to aging even without further exposure to loud noises. In addition to noise and age, other, non-acoustic factors have been shown to affect the ability to hear. For example, hearing loss can be a secondary symptom of other medical conditions, and it has been linked to the use of certain prescription and recreational drugs.

Noise can cause permanent hearing loss by two main mechanisms. Extremely loud, impulsive, short duration sounds can cause ruptures in the eardrum as well as damage to middle ear structures. These types of damage are described further in the impulse noise section of this report. While permanent hearing losses can occur from this type of exposure, most threshold shifts of this kind are only temporary; hearing levels have been shown to return to normal up to a few weeks after the original exposure (Ryan, Kujawa, et al., 2014).

Lower levels of noise can cause hearing loss when exposure is extended to longer periods and repeated over years. This type of damage is associated with degradation of the highly sensitive hair cells in the

⁷ Acquired hearing loss is a hearing threshold shift that a person is not born with.

inner ear that transduce the vibrations in the basilar membrane due to sound signals into electrical signals that are then transmitted by nerves to the brain. These hair cells do not regenerate after being damaged, and thus this degradation is irreversible. Due to resonance frequencies in the outer ear canal, the frequency ranges around 4 kHz are amplified. This is why the 4 kHz frequency range is the first to be affected by permanent threshold shifts (Ryan, Kujawa, et al., 2014). Additional recent research has given insight into the molecular and cellular mechanisms by which hearing loss occur within the inner ear structures, and there has been some early progress in stem cell based therapies and treatments that may recover early damage due to loud noise exposure (Basner, Babisch et al., 2014).

One area where there has been recent research developments is in hearing loss in teens and young adults due to excess noise exposure from portable music listening devices. Noise levels generated by earbuds and headphones can be much higher than would be experienced from environmental noise. Increased use of these personal listening devices in teens and young adults may increase these age groups' risk of hearing loss in the short term as well as later in life. A review by the World Health Organization of five studies on this subject showed that the odds of developing permanent hearing loss for regular personal listening device users might be about four times higher than for non-users. However, there was little evidence in the studies reviewed that would allow a relationship to be developed between the sound levels experienced by the user, and the degree of threshold shift experienced. Additionally, the studies in the review may have biased results, and there was no data linking hearing loss later in a person's life to personal listening device use (Kowalska, Zabarowski, 2017).

2.1.4 Summary and Research Gaps

2.1.4.1 Summary of Current State of Research and Understanding

The basic understanding of the noise levels that cause permanent degeneration of hearing ability has not changed substantially since the Levels Document was published.

The Levels Document based its level to protect public health and welfare from hearing loss on three syntheses from the 1960s and 1970s in combination with a separate public health survey reporting basic hearing levels of different population groups. From this "Critical Percentile" analysis, a baseline noise level of 73 dB, that would protect against a maximum of 5 dB noise-induced permanent threshold shift, was derived based on 8 hours of exposure, 5 working days per week, for 40 years. Different levels are given with adjustments for intermittency and 365 days of exposure, 24 hours a day. The final level requisite to protect public health and welfare from hearing loss reported by the Levels Document for 24 hour, continuous environmental noise exposure 365 days a year was 70 dB $L_{Aeq,24hr}$, regardless of the source or type of sound.

Since the original research performed in the 1960s and 1970s, there have been few additional studies published on the effects of continuous occupational noise exposure on hearing levels or hearing loss. The original databases used by different standards making groups have not been updated significantly since these early studies. However, different studies using different analysis procedures and assumptions from the same researchers have led to slightly different results. The later studies, based on the same original databases, were used by the International Standards Organization to derive algorithms to predict NIPTS at different exposure levels and durations. The ISO standard has been generally

accepted and used by many regulatory bodies around the world to set standards for workplace and environmental noise exposure. The most recent update of these standards was in 2013, but any updated equations still utilize the original data from the 1960s and 70s. The differences in assumptions used in the Levels Document's analysis and the ISO standard analysis explains most of the differences between NIPTS predicted in these documents.

Also of note is the additional discussion included in the Levels Document concerning the difference between the EPA's responsibility to protect against environmental noise and other agencies' requirements to set occupational health and safety standards. It is expected therefore, that the extrapolations and assumptions used by the Levels Document yielded a lower final recommendation than that presented in other occupational noise standards or literature.

New understanding of the physiological, molecular, and mechanical components of the ear that are affected when exposed to excessive noise may result in new medical treatments that would be able to restore hearing after exposure to loud sounds. Such research is in the early stages of development. Additional recent research has explored the effects of personal listening device use on hearing abilities; however, this research is not yet comprehensive enough to provide decibel level relationships to hearing threshold shifts.

2.1.4.2 Research Gaps

Although there is a generally accepted standard for effects of continuous noise exposure on hearing levels, most of the studies used to develop this standard are cross sectional studies. There are limited data that has directly related subjects' exposure to noise over a timeline of many years to degradation of hearing ability or threshold shifts after certain periods. More longitudinal studies would improve the understanding of how cumulative noise exposure affects human hearing in the short and long term, how the hearing system recovers from temporary threshold shifts, and how excessive exposure contributes to hearing degeneration due to aging.

Additional research may be necessary to determine how medical conditions and use of prescription or other drugs or treatments affect a person's hearing levels directly, or their susceptibility to damage from excessive noise exposure. Because the use of personal listening devices is widespread, more research should also be performed to determine how these devices affect risks of hearing loss in both young adults and older age groups. This requires measurement of noise levels experienced by individuals listening to these devices, as well as longitudinal measurements of effects over longer time spans.

2.2 Activity Interference

2.2.1 How the Levels Document Addressed Activity Interference

The Levels Document proposed noise levels to protect against speech interference in both indoor and outdoor environments. The document stated that indoors, the maximum noise level that will permit relaxed conversation with 100 percent sentence intelligibility is 45 dB $L_{Aeq(24)}$ (assumes a 1.1 meter or greater distance between listener and talker within the same room⁸). The document defined sentence

⁸ Due to the reverberation of sound off walls and other boundaries of the room, at distances of 1.1 meters or greater the level of speech is more or less constant throughout a room.

intelligibility as the percentage of the key words in a group of sentences that are correctly understood by the listener.

The Levels Document assumed a 15 dB reduction in sound level between outdoor and indoor environments (an average reduction assuming partially open windows), so it translated the indoor noise level of 45 dB to an outdoor level of 60 dB $L_{Aeq(24)}$. Outdoors, speech intelligibility decreases with the distance between the listener and talker. At 2 meters between the listener and talker, 60 dB L_{Aeq} will allow for normal conversation with 95 percent sentence intelligibility; speaking in a raised voice will allow for the same sentence intelligibility with noise levels of 66 dB (see Levels table D-1). Sentence intelligibility of 95 percent is considered satisfactory for most situations, because in normal conversation many words can be inferred based on the context (especially if they are familiar words). The Levels Document noted that speech intelligibility is affected by whether the noise and speech frequencies overlap, which makes speech intelligibility more difficult. In addition, as background noise levels increase, participants in a conversation have to either move closer together or raise their voices in order to be understood.

The Levels Document also assumed that annoyance was caused by activity interference, and the levels proposed for protection of the human population against annoyance focused primarily on preventing speech interference. To protect against activity interference and annoyance in residential areas, Levels added a nighttime weighting. The outdoor level was given a 5 dB margin of safety to protect against “non-acoustic” effects that differ between people, locations, and study populations. The document therefore recommended the maximum noise levels to prevent interference of speech and other activities as L_{dn} of 45 dB indoors and 55 dB outdoors for all types of environmental noise in residential areas (see Section 3.3, Annoyance, for more information about noise levels to protect against annoyance).

2.2.2 Current State of Research

2.2.2.1 *Speech Interference*

Since the Levels Document was published, there has been some additional research on the impact of noise on speech interference. Most of this research addresses a specific aspect of speech interference, and does not explicitly confirm or refute the levels to protect against speech interference that are described in the Levels Document. Given that the acoustics and physical attributes of hearing and speech communication were well understood at the time the Levels Document was published, it is reasonable to conclude that the noise levels to protect against speech interference proposed in that document have not changed.

Several recent studies on speech interference refer to the signal to noise ratio (S/N), or the difference in A-weighted sound pressure level between a person’s speech and the background noise source. For example, if a person’s speech were the same noise level as traffic noise, the S/N would be 0 dB, while a negative S/N value means that the background noise level is louder than the speech level. Although the Levels Document did not use the S/N measure of speech interference, it did discuss how speech interference is affected by the volume of the speaker’s voice with constant background noise, which is essentially a description of the S/N ratio.

The 2000 WHO *Guidelines for Community Noise* (Berglund et al) describes the relationship between speech interference and S/N. The report notes that speech interference is a masking process, whereby interfering noises prevent speech from being understood. As background noise increases, people raise their voices; although this improves speech intelligibility, it does put a strain on both the speaker and listener. Indoors, speech intelligibility also depends on the reverberation characteristics of the room. Very high amounts of reverberation makes intelligibility more difficult, especially when combined with background noise. Based on studies from 1985 and 1990, the report states that for 100 percent sentence intelligibility in listeners with normal hearing, the signal to noise ratio should be at least L_{Aeq} of 15-18 dB. The report notes that this implies that indoors in small rooms, background noise levels above about 35 dB interfere with speech intelligibility at a normal speech volume (speech level of 50 dB). With a raised voice, one can expect 100 percent speech intelligibility up to background noise levels of 55 dB, and with a “straining” vocal effort speech can be intelligible in up to 65 dB of background noise.

Berglund et al noted that this recommended level of 35 dB is lower than the recommended noise levels to protect against speech interference described in the Levels Document, but does not provide an explanation of why this might be the case. One potential reason for the difference is that the two reports used different assumptions about typical/comfortable speech levels, outdoor to indoor noise insulation, and the reverberation characteristics of typical rooms, making comparison difficult. In addition, the 15-18 dB S/N recommended in the WHO report is to allow for 100 percent speech intelligibility. As noted above, 100 percent speech intelligibility is not typically needed for effective communication.

Studies that are more recent have evaluated the impact of noise on speech interference in different outdoor environments. Alvarsson et al (2014) studied the effect of aircraft noise on speech intelligibility in an outdoor living space (in a pergola). Study participants listened to recordings of aircraft noise as well as a list of 50 words. The study found that aircraft noise adversely affected speech intelligibility starting from aircraft noise levels of approximately 55 dB(A) or an S/N(A) of 0 dB. This is similar to the Levels Document, which stated that background noise levels of 60 dB L_{Aeq} outdoors will allow for normal conversation with 95 percent sentence intelligibility. The study also investigated alternate models for measuring speech interference, but found that the simple A-weighted S/N ratio was nearly as good an indicator of speech intelligibility as were two more complex models.

Lee and Jeon (2011) tested the effects of combined noise sources on speech transmission in open public spaces. The test was conducted in a laboratory setting, and the authors used a computer to model the noise of an open public space surrounded by buildings, as well as road traffic noise and stationary and impulsive construction noise. Study participants listened to recordings of words and were asked to rank their “listening difficulty” on a scale of 1 to 4. Participants were also assigned a word intelligibility score based on the percentage of words they understood correctly. The study found that speech intelligibility for combined noise sources in an urban space was most affected by the temporal characteristics of construction noise. Speech transmission performance decreased as construction noise levels increased by 15 dB in sound fields exposed to steady state noise; however, speech transmission performance did not change as much in the situations with impulsive construction noise. The study also found that the

subjective measurement of listening difficulty rating had greater variation than the word intelligibility scores, and seemed like an inappropriate measure of speech transmission in noisy urban areas.

Other research has evaluated particular elements of speech interference that are out of the scope of this review. For example, studies have investigated the optimum speech levels for effective communication (Kobayashi and Morimoto, 2007), as well as speech intelligibility in particular settings, such as for passengers on a train (Shimokura and Soeta, 2009; Maffei et al 2012).

2.2.2.2 Other Activity Interference

Studies on other types of activity interference primarily rely on surveys of residents to correlate annoyance or disturbance during particular activities to noise levels. Bartels et al (2015) conducted a study with 55 individuals living near Cologne/Bonn airport in Germany. Study participants were asked to rate their annoyance on an hourly basis, and an individualized L_{Aeq} was calculated for aircraft noise based on information about the participant's whereabouts, the window position, and a potential outdoor to indoor attenuation of the aircraft noise level. The study found that annoyance to aircraft noise was higher while participants were watching TV/listening to radio, relaxing, and eating (see Table 5). Aircraft noise occurring during physical activities was perceived as less annoying. The study found no significant effect of conversation disturbance on annoyance, but the authors noted that this contradicts prior research and the expectation of a causal relationship between speech interference and annoyance. The authors suggest that annoyance may be higher for watching TV/listening to the radio than for speech communication because people in conversation adjust their speech volume to adapt to noise, and someone can ask the person they are speaking with to repeat if they did not hear. However, the frequent and intermittent nature of aircraft noise means that someone would have to adjust the volume on the TV repeatedly in order to hear, which they might find more annoying.

Table 5: Table 3 from Bartels et al 2015 showing the correlation between annoyance to aircraft noise and various activities

Variable	B	SE	p
Intercept	0.851	0.090	<.001
Conversation	0.036	0.049	.464
TV/radio	0.183	0.053	<.001
Mental work	0.093	0.053	.080
Physical activity	-0.160	0.051	.002
Leisure activity	-0.008	0.089	.928
Relaxation	0.336	0.066	<.001
Socializing	-0.030	0.055	.590
Eating	0.142	0.046	.002
Personal care	0.186	0.143	.194
$i L_{Aeq,AC}$	0.026	0.003	<.001

Note: The table shows the results of a generalized estimating equation (GEE) analysis to test the contribution of various activities on aircraft noise annoyance in the previous hour. Annoyance was rated on a scale of 1-5, and aircraft noise was mentioned in the question. A positive regression coefficient (B) means that annoyance was rated higher when this activity was carried out; a negative regression coefficient indicates lower annoyance when this activity was carried out (Bartels et al, 2015).

Hall, Taylor, and Birnie (1985) used surveys to determine the relationship between activity interference and annoyance. The activities included indoor and outdoor speech, getting to sleep, and awakening (see

section 3.5, Health and Sleep Impacts, for more information on noise and sleep disturbance). The authors found that all of these activities were predictors of annoyance with a significant effect. For speech interference, there was no significant difference by noise source (air, road, and rail).

2.2.3 Summary and Research Gaps

There have not been substantial changes to the information presented in the Levels Document on speech interference since that document was published. There have been few recent studies on the noise levels at which speech is disrupted, and those few studies do not seem to update the overall finding from the Levels Document that speech is likely to be disturbed at 45 dB L_{dn} indoors and 55 dB L_{dn} outdoors in residential areas. Much of the ongoing research on speech interference focuses on particular aspects of communication, such as how to best measure speech intelligibility, or on particular settings, such as on train cars or urban public spaces. Therefore, we did not identify any major research gaps within the topic of speech interference.

For disruption of other activities, such as watching TV, relaxing, and other recreation, findings are based on asking about activities in surveys of annoyance. For a given noise level, some activities have been found to lead to greater annoyance. These include interference with speech communication, watching TV, relaxing, and eating. Other factors that affect annoyance findings are described in detail in the Annoyance section of this report. Asking about activities during surveys of annoyance to noise may help to clarify the relationship between noise levels, activity interference, and annoyance.

2.3 Annoyance

Annoyance, or a person's individual adverse reaction (Pederson, 2007), from environmental noise is often described as the main or most important effect of noise by international noise experts (Guski, Schreckenber, Scheumer, 2017). It is a complicated, difficult to model issue, with research results often differing substantially within and between different studies. Annoyance can be both the cause of and a response to other adverse effects; however, it is important to discuss annoyance as a standalone response to environmental noise exposure.

2.3.1 How the Levels Document Addressed Annoyance

The Levels Document reported that annoyance was caused by activity interference. The noise levels proposed for protection of the human population against annoyance focused on preventing primarily speech interference. By setting a level of acceptability to prevent speech interference, the Levels Document assumed that these levels would prevent widespread reports of annoyance from affected populations as well.

The Levels Document also included discussions of results from a number of annoyance survey studies. Three of these studies were on annoyance to aircraft noise, and one was a study of perceived noisiness of automobile traffic in urban residential areas. Results from the three aircraft annoyance studies were used to justify a prediction of annoyance impacts at the recommended, speech-interference-based noise levels; the Levels Document did not consider the urban noise annoyance data in its impact predictions. The aircraft annoyance studies were performed in the United States and the United Kingdom between 1961 and 1971, and included 9 airports in total. The surveys used yes or no questions about activity interference and annoyance to assess whether a respondent was highly annoyed or not.

The combined results from these surveys are shown in Figure 8. These data points are aggregations of responses at ranges of noise exposure levels across the data sets used in the analysis from which this figure was drawn. It is not specified by the Levels Document or the source how these aggregations were performed.

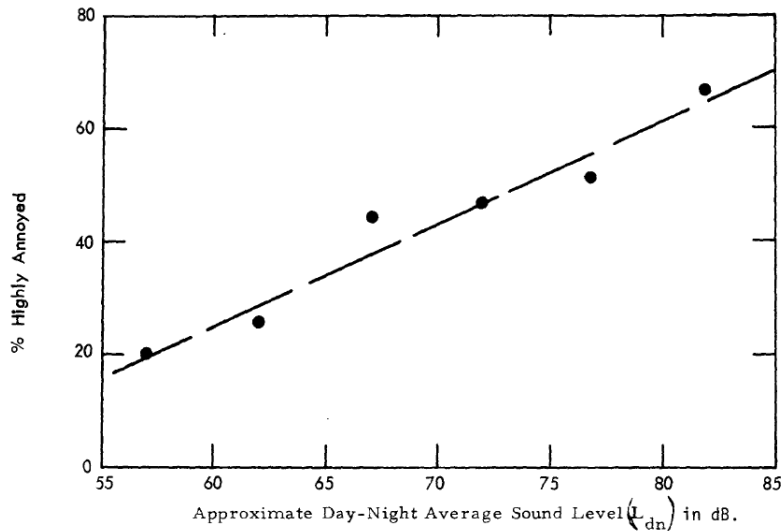


Figure 8. Levels Document combined results from London surveys and US survey: percent highly annoyed relationship to L_{dn}

The results shown in Figure 8 appear to be linear over the exposure range, and the Levels Document notes that this figure makes it seem like the results from the three annoyance surveys are consistent. The U.S. aircraft noise annoyance study also provided a relationship between the percent of the population that issued complaints about aircraft noise ($\sqrt{\%C}$), and the percent of the population that indicated they were highly annoyed (%HA). This relationship is shown in equation 1. The study that proposes this relationship does not provide metrics or measures for how reasonably this curve fits the data presented.

$$\%HA = 12.3\sqrt{\%C} + 4.3 \tag{1}$$

The Levels Document combined the apparently linear results from Figure 8 and the relationship in equation 1 into a single relationship between the environmental noise level and the percent complaints. The resulting relationship is used to derive the prediction that at 55 dB, 1 percent of the population is likely to complain about environmental noise, and 17% of the population may indicate being highly annoyed in an annoyance survey.

The authors of the Levels Document decided these results were not comprehensive enough to base a recommended sound level on them. Specifically, the Levels Document states, “the levels of environmental noise that are associated with annoyance depend upon local conditions and attitudes, they cannot be clearly identified in terms of the national public health and welfare.” The recommended sound level presented is 45 dB L_{dn} indoors and 60 dB L_{dn} outdoors for protection against speech interference. The recommended outdoor level was given a 5 dB factor of safety, making the final

recommended level of outdoor environmental noise 55 dB L_{dn} . The 5 dB factor of safety is intended to protect against “non-level related factors” that differ between people, locations, and study populations.

The Levels Document ended the discussion on annoyance with a summary of predicted impacts at the recommended level of 55 dB L_{dn} , repeating the prediction of 17% highly annoyed and specifying that this level is dependent on attitude and other non-acoustical factors. The prediction of 1% of the exposed population complaining is used to justify acceptance of 17% of people being highly annoyed. A number of caveats should be noted concerning the studies used in the Levels Document’s analysis of noise annoyance:

- 1) The three survey studies used activity interference based questions to assess annoyance. Only in the London surveys was one direct annoyance question asked.
- 2) The three studies all classified a respondent as being highly annoyed if they scored in the upper 50% of the annoyance scale.
- 3) While the London surveys contained noise exposure data that could be converted to L_{dn} , the U.S. surveys reported noise exposure only in Composite Noise Ratings (CNR). CNR is a weighted metric that is calculated based on the maximum noise level of a single event and the number of events. The Levels Document converts results to L_{dn} . Accurate conversions between CNR and L_{dn} require the number of events and the peak sound levels during those events. However, in the absence of these data, the authors of the Levels Document used approximate conversions. These approximations introduce inaccuracies in the graphs and data presented by the Levels Document, and thus the resulting predictions as well.
- 4) The data presented in Figure 8 (Figure D-13 in the Levels Document) comes directly from Borsky’s analysis of the London and U.S. surveys. It only includes percent highly annoyed from respondents categorized as having moderate fears of the sound source or a moderate belief of misfeasance by the aircraft operators, and ignores responses from high or low fears or feelings of misfeasance. Data from people with moderate feelings about the sound source were said to represent an average of the dataset as a whole. (Borsky, 1973).

The possible sources of uncertainties and inaccuracies due to the caveats laid out above call into question the accuracy of the predicted percent highly annoyed at the recommended levels of environmental noise in the Levels Document. This is in addition to the small number of survey studies, data points, and study populations used in this analysis. While the proposed exposure-response relationship simplifies predictions of adverse effects, the narrow study population and studies included make it impossible to apply this relationship to the nation as a whole. For these reasons, any comparison of these results with other, more recent synthesis studies should be made with caution.

The caveats above indicate that the Levels Document generally did not consider the complex physical, physiological, and psychological process by which a person becomes annoyed to environmental noise. In order to model the exposure-response relationship accurately, a comprehensive understanding of this process is necessary which takes into account the multiple factors that affect a person’s attitude toward noise. The following section will discuss these factors in depth as they relate to noise exposure and annoyance.

2.3.2 The Annoyance Exposure-Response Model

In order to better assess the findings of noise annoyance survey research and understand the large variation in results over the last 60 years of research, it is important to recognize the theoretical pathway by which an annoyance response is produced from a noise source. Figure 9 shows an example of such a pathway or model. The remainder of this sub-section describes each element of the model and how it affects the overall exposure-response relationship.

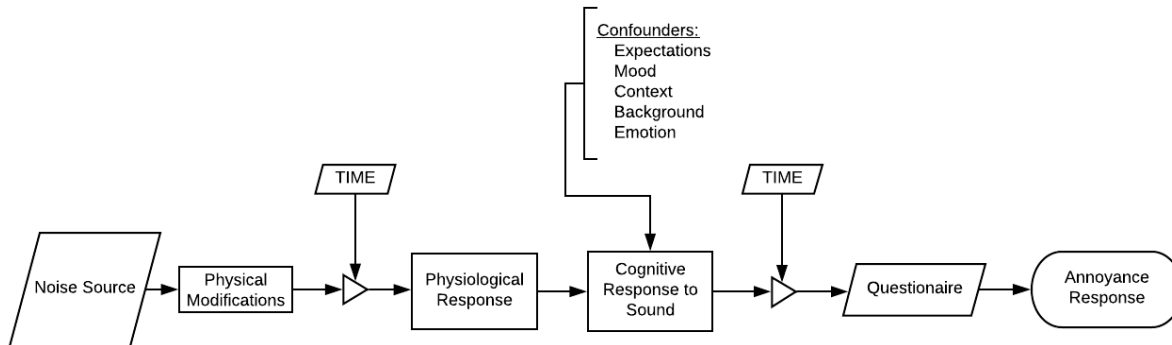


Figure 9. Annoyance exposure-response model.

2.3.2.1 Noise source

The noise source can be a moving source such as a transportation mode (i.e., air, rail, or road), or it can be stationary like a quarry or a wind turbine. The characteristics that differentiate the noise from various sources include the sound level produced, frequency content of the sound, intermittency, and the presence of pure tones. For example, highway noise tends to be a continuous noise source with broad frequency content, whereas aircraft noise consists of individual events that have more noticeable pitch or pure tones due to the operation of turbines or propellers.

The metric by which sound is measured and described can also affect how the annoyance response is quantified. While instantaneous sound levels can be useful for describing short-term, physiological effects of noise and sound, longer term averaging metrics are more apt to describe longer-term impacts of noise exposure like annoyance. While L_{dn} is most often used to relate noise exposure to annoyance survey responses, there are both benefits and drawbacks to its use. L_{dn} accounts for a full day, including nighttime sensitivity, as well as frequencies audible to the human ear. L_{dn} does not account for aspects of sound such as tonal content, impulsiveness, sharpness, and other qualities that have been shown to have a large effect on annoyance, and therefore are rarely included in published exposure response relationships.

2.3.2.2 Physical Modifications

Physical modifications describe how the sound travels from the source to the receiver. The ground over which the sound waves travel, the presence of natural or infrastructure barriers, and the weather can all have an effect on the levels of sound actually experienced by a person. Some of these factors are designed specifically to attenuate the sound levels reaching a receiver, like highway sound barriers or residential buildings with exterior walls designed to absorb sound rather than transmit it.

The most obvious physical modifications are the differences in levels experienced indoors versus outdoors. The Levels Document assumed that outdoor noise levels were about 15 dB higher than indoor levels. The authors came to this assumption based on a 1971 study by the Society of Automotive Engineers on indoor household noise from aircraft. This study reported average indoor noise levels in warm and cold climates around the country. The study reported reduction of decibels between indoor and outdoor noise levels for both a “windows open” and a “windows closed” situation in both region types. The approximate national average difference for the windows open scenario was 15 dB, while for closed windows the approximate difference was 25 dB. The Levels Document chose the more conservative, windows open estimate for their analysis of levels to protect the public health and welfare.

Other research, both in the 1970s and more recent, have found a range of differences between noise measurements indoors versus outdoors. Overall, the open windows condition usually shows a 10-15 dB reduction between outdoor and indoor sound levels, while the windows closed condition shows a 20-30 dB reduction. The difference can change with the frequencies and qualities of the sound striking the building, the geometry of the building, and the materials with which the building is constructed. In addition, most studies do not study the actual sound transmission characteristics of the building walls themselves, only the indoor noise levels in comparison with the outdoor ones. Thus, measurements include indoor noise sources such as noise from appliances or HVAC systems, or noise produced by building occupants (Locher, Piquerez, et al., 2018; Naim, Gulliver, Fecht, Hansell 2017).

2.3.2.3 Physiological Response

The physiological response represents the physical, sensory, and neurological response to noise, such as inner ear mechanisms and how the brain receives and processes acoustic information. It is well understood and can be studied objectively through laboratory studies where test subjects are stimulated by different types of sounds. The way a sound is perceived physiologically is affected by slight differences in people’s hearing ranges, neurological sensitivity to different frequency ranges, and differences in how quickly people adapt to changing sound stimuli. Relationships between physical sounds and how the brain perceives the sound can be measured by asking targeted questions using well-defined descriptive terms for the sounds. Studying how humans perceive changes in sound level, tone, or other aspects is also an effective way of describing these physiological phenomena. (Zwicker, Fastl, 1999)

2.3.2.4 Cognitive Response to Sound

Cognitive response to sound is the most difficult element in the annoyance exposure-response model to study, and is the main reason why the Levels Document did not focus on annoyance for their noise level recommendations. The Levels Document referred to these effects broadly as “attitudinal biases” towards sound that may not have anything to do with the noise itself or even the environment in general.

The confounders shown in Figure 9 list a few examples of attitudinal biases toward sound. Prior experiences with a certain type of noise, expectations about noise, beliefs about whether or not the noise can be abated, beliefs about the necessity of the sound source, or basic changes in emotional

state can all have an effect on a subject's annoyance response. Individual noise sensitivity is also recognized as an important factor in how a person responds to environmental noise (Pederson, 2007).

It is difficult to quantify the effect of confounding factors in cognitive response on annoyance results. Measurement of these effects relies on people's answers to survey questions and cannot be objectively measured, so it may be impossible to know if a person's answers to these questions accurately reflect the annoyance response to noise. In addition, it is difficult to target these factors as independent variables in analysis of exposure-response relationships. Researchers who find correlations between noise exposure and annoyance often concede that large variations in data points should be expected due to difficulties measuring cognitive response variables (Miedema, Oudshoorn, 2001). Some of these effects are easier to measure than others. Age, length of time as a resident in the study region, the study region itself, and income brackets can all be measured objectively as part of demographic questions in annoyance surveys. Even so, researchers have found that subjective attitudinal factors, like fear of the sound source or expectations of changes, have a substantially larger effect on annoyance than demographic variables (Schreckenberg, Schuemer, 2010).

Overall, researchers have found that the effects of the confounding "non-acoustic" factors can account for up to 60 percent of the range in annoyance ratings seen in annoyance survey studies (Kroesen, Molin, van Wee, 2008). Other researchers have shown that certain non-acoustical factors, specifically negative expectations concerning the sound source and fear of the sound source, can predict noise annoyance more accurately than the sound exposure level (Schreckenberg, Schuemer, 2010).

2.3.2.5 Survey Questionnaire

The survey design can affect how respondents report annoyance. Survey design may include differences in negative and positive connotations, usage of certain words, and the rating scales used in the surveys. Early surveys from the 1960s and 1970s, varied widely in how they assessed how annoyed a respondent was to noise. Some surveys asked a direct annoyance question, and others determined overall annoyance from a set of activity interference ratings. This variation makes it difficult to compare results from early surveys directly. While performing mathematical conversions is sometimes an option, these are often approximations and thus introduce more uncertainty in results.

The International Commission on Biological Effects of Noise (ICBEN) has published standard survey questions to assess annoyance to environmental noise, with the most recent standard published in 2003. Additionally, the Transportation Research Board has sponsored recent research that led to the development of protocols for conducting large-scale social surveys on aircraft noise annoyance. These new protocols are currently being used by the FAA (Miller, Cantor, et al., 2014). In exposure-response studies, annoyance questions are usually asked on a 5-point verbal, or an 11-point numerical scale. The 5-point verbal scale has 5 options of responses ranging from "not at all annoyed" to "extremely annoyed." The 11-point numerical scale ranges from 0 to 10, with 0 indicating not at all annoyed and 10 indicating extremely annoyed. The responses from these questions are often converted to the "percent highly annoyed" metric. On the 5-point scale, respondents indicating in the top two categories (top 40%) are labeled as highly annoyed. In the 11-point scale, respondents indicating an 8 or higher (top 3 categories or top 27%) is labelled as highly annoyed. While the specific questions asked can have a large

effect on annoyance results, the acceptance of these standard procedures has greatly increased the comparability of data across studies.

2.3.2.6 Time

Time affects the annoyance response at two locations in the model in Figure 9. The first time input describes short-term effects at the biological hearing system level, and the second describes longer-term cognitive effects.

Short-Term Biological Effects: The time input between physical modifications and physiological response reflects the human auditory system's ability to adjust its own sensitivity depending on short-term changes in sound exposure. This concept is very similar to how the iris within the human eye opens and closes the pupil depending on the amount of light to which the eye is exposed. By reducing sensitivity to rising amplitudes of sound, the ear can proactively prevent certain amounts of discomfort, even low levels of pain. However, this effect only works to the extent that rates of changes in sound levels are slow enough and the changes are small enough for the ear to compensate. Just as walking from a dark space into bright sunlight can be painful or make a person's eyes water, impulsive noise is often more painful or damaging to the human auditory system because there is not sufficient time for the hearing system to make the necessary adaptations.

Long-Term Cognitive Effects: Several long-term time factors affect a person's annoyance response to noise. To a certain extent, people who are exposed to noise for months or years report less annoyance to these noises because they have been conditioned to, or "gotten used to," these environmental noises. For example, people who have lived in cities for many years often report being less annoyed by roadway traffic noise than those who have moved to the area more recently. However, if noise is seasonal or intermittent, annoyance can actually be higher than for constant noise levels. The time of day, as well as season of the year are also time-related variables that affect the annoyance response after the cognitive response. The time between hearing a noise and responding to survey questions can also affect the resulting annoyance response. Additionally, there is evidence that the actual exposure-response relationship across a population may change slowly over time with changing public attitudes toward environmental noise, the economic vitality of a region, or changes to the noise sources themselves (Guski, Schreckenberg, Schuemer, 2017).

2.3.3 Recent Studies and Syntheses

Since the Levels Document was written, a wealth of annoyance survey data have been published. Earlier studies tend to focus on specific noise sources like aircraft noise or road traffic noise. Prominent researchers have combined the data from many different mode-specific studies into synthesis reports. These studies relate percent highly annoyed and raw annoyance ratings (0 to 100) to the day-night average sound level.

Schultz published one of the first syntheses of social surveys on noise annoyance in 1974. In this highly influential paper, Schultz offered a predicting equation for community reaction to L_{dn} based on 11 social surveys spanning multiple noise sources. Schultz only used survey data with comparable bases for categorizing a respondent as being highly annoyed or not. Survey data that were not based on easily comparable highly annoyed metrics were not included in his regression. While the resulting

approximation curve was the best available predictor of community annoyance at the time, these results did not take into account differences in sound sources, non-acoustic factors, and other variables that are now known to have as large or larger effects than noise exposure on annoyance responses (Schultz, 1978).

In 1989, Sanford Fidell published an updated version of the Schultz curve that combined studies performed since Schultz's original paper was published with the data originally analyzed by Schultz. Fourteen newer studies were included in the 1991 report, all published between 1978 and 1985. Similar curve fits were performed in Fidell's paper as were included in the Schultz publication. The results in Fidell's updated analysis do not vary significantly from Schultz's results. The updated fits show marginally higher annoyance predictions at lower sound levels and slightly lower annoyance at higher sound levels using the same quadratic curve fitting method as Schultz (Fidell, Barber, Schultz, 1989).

In 2001, Miedema and Oudshoorn published another important annoyance synthesis. Based on similar survey data as the Fidell study obtained in the 1970s and 1980s, this statistical analysis was one of the first comprehensive studies to offer different exposure-response relationships for different transportation modes in a combined study. Miedema and Oudshoorn included data from Europe and the United States in this synthesis. Unlike Schultz, Miedema and Oudshoorn computed the probability that a person exposed to a certain noise level would respond with a certain annoyance rating on a 0 to 100 point scale. Relationships of percent highly annoyed to L_{dn} were calculated from these probability equations and are included as an alternative result for ease of calculation (Miedema, Oudshoorn, 2001).

The most recent major synthesis of annoyance survey data was published in support of the World Health Organization's (WHO) development of noise level recommendations for the European region, completed in 2018. This synthesis of over 100 studies presents exposure-response relationships by transportation mode. The analysis used data from studies performed since 2000. The combined dataset represents annoyance survey responses from over 60,000 respondents. This synthesis includes a wider breadth of regions, economies, and countries in the regression analysis than many other studies to date.

Figure 10 through Figure 12 show the results of the regression analyses for aircraft, road traffic, and rail noise from the WHO study. WHO displayed the Miedema and Oudshoorn relationships for comparison with the data from studies reviewed by the WHO researchers and on which the WHO regressions are based. The data points used in the WHO regressions were obtained using the regressions in the studies reviewed. The researchers took values of the regression equations at 5-decibel intervals, and then performed an overall regression using the full set of data points from all studies reviewed for each transportation mode. Thus, the equations provided can be thought of as averages of regressions from different studies, not regressions of the actual survey data from the original studies. The full range of study data is thus not shown on the graphs nor is it included in the WHO regressions. Note that the noise levels use the L_{den} metric.

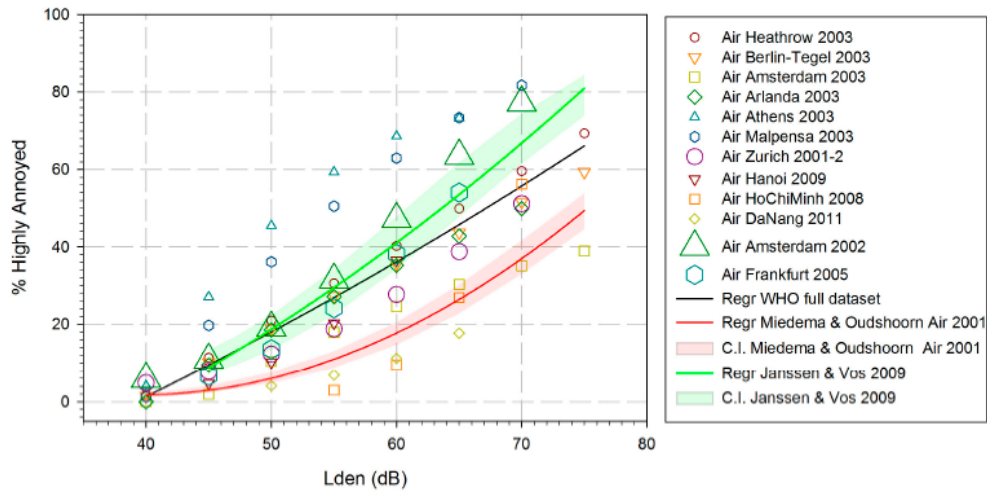


Figure 10. Percent highly annoyed related to aircraft noise levels in different regions. The black line here shows the correlation derived by the WHO researchers. The red line shows Miedema and Oudshoorn's correlation

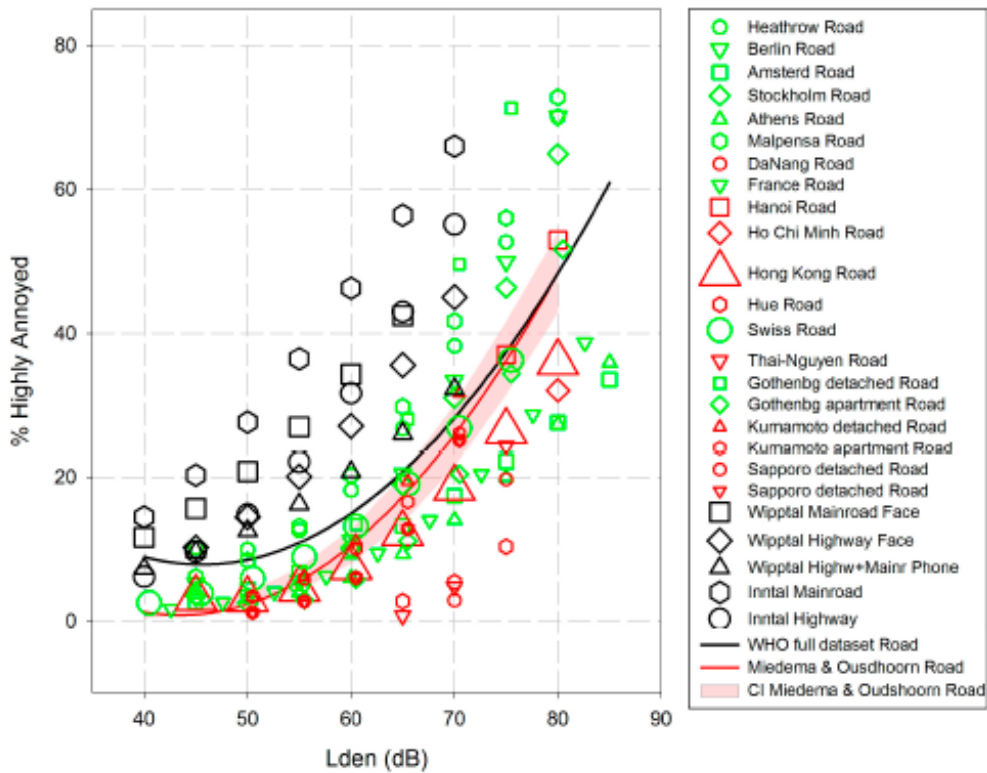


Figure 11. Percent highly annoyed related to roadway noise in different regions. The black line here shows the correlation derived by the WHO researchers. The red line shows Miedema and Oudshoorn's correlation

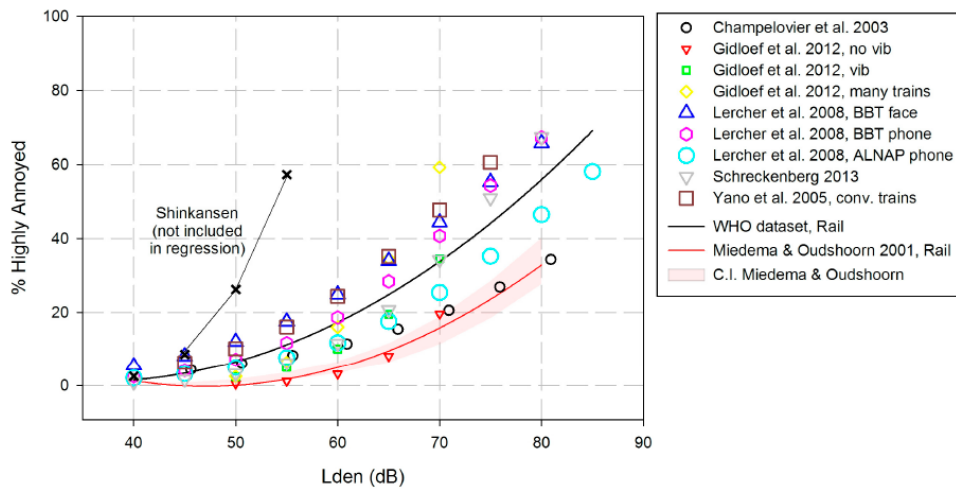


Figure 12. Percent highly annoyed related to railway noise in different regions. The black line here shows the correlation derived by the WHO researchers. The red line shows Miedema and Oudshoorn’s correlation

One notable feature of the data depicted in the WHO results is the large range in percent highly annoyed at some sound levels. For example, for aircraft noise, percent highly annoyed ranges from 10% to 70% at 60 dB. For road traffic noise, the range is about 5% to 50% highly annoyed at 60 dB L_{den} . The use of L_{den} in the WHO studies reflects an attempt to account for slightly higher noise sensitivity in early evening hours. The use of this metric may make it more difficult to compare results from this study to other study results. The smallest range is found for railway noise, where the percent highly annoyed ranges from 2% to 25%. The large ranges in percent highly annoyed across many studies suggest that there are more variables that affect a subject’s annoyance response to noise than the levels of noise to which that subject is exposed. As discussed in the previous section, the major contributors to these variations could be due to differences in cognitive response to noise between subjects and study populations (Guski, Schreckenberg, Schuemer, 2017).

2.3.3.1 Comparison between Studies

Table 6 shows a comparison of the results given by different studies discussed above. The values of percent highly annoyed are the values given by the regression equations in each study at 55 dB L_{dn} . The results given by the Levels Document are also presented below, but comparison to this highly annoyed statistic should be done with care, as discussed previously.

Table 6. Comparison of results from different annoyance syntheses at 55 dB L_{dn} .

Study	Year	%HA	Notes
WHO Aircraft	2014	26.7	Survey data from Europe and Asia only
WHO Roadway	2014	11.0	
WHO Railway	2014	11.3	
Miedema Aircraft	2001	11.0	Survey data from North America, Europe, and Australia
Miedema Roadway	2001	6.6	
Miedema Railway	2001	2.4	
Fidell	1991	8.2	Combination of air, road, and rail noise
Schultz	1978	3.9	Combination of air, road, and rail noise
Levels Document	1974	17	Only aircraft noise; caveats discussed in Section 3.3.1

From the Miedema and WHO results shown in Table 6, aircraft noise is perceived as more annoying than rail and roadway noise. This is probably due to a few different factors. When noise contains more pure tones, as is the case with aircraft noise, people usually indicate they are more annoyed. The intermittency of aircraft noise might also be more annoying because people cannot habituate to intermittent sounds in the same way as continuous sounds. Feelings about the nearby airport or aircraft in general will also play a role, as these are confounding cognitive factors.

One feature evident in the data presented in Table 6 is the apparent rise over time in percent highly annoyed between 1978 and 2014. This is especially observable in the case of aircraft noise. One possible explanation for this increase is the different regions and countries included in the different studies. The WHO study is the first to include a substantial amount of data from Asian countries. On the other hand, U.S. studies are not included in the WHO report, mainly due to the lack of U.S. annoyance studies performed after the 1980s. Other researchers have noted that reported annoyance to aircraft noise seems to have risen since the studies performed in the 1970s. Different methodologies between old and new studies, increases in how quickly aircraft operations change at many airports, and changing attitudinal factors have all been discussed as possible reasons for this apparent increase. It is difficult to know if there are actual annoyance changes over time due to the lack of longitudinal studies performed over a period of time in the same region. More consistency in regions and methodology across the body of research will help control for certain confounding variables and thus improve understanding of annoyance to noise (Guski, 2017).

2.3.3.2 Studies on Confounding Factors

A few recent studies have attempted to examine how much activity interference and attitudinal variables affect annoyance responses to noise. Specifically, a study in 2010 and a study in 2015 used statistical techniques to analyze which non-acoustical factors explained the variance seen in the exposure-response relationships like the ones studied by the WHO researchers (Schreckenber, Schuemer, 2010; Bartels, Marki, Muller, 2015). The 2010 study was able to show through beta coefficient analysis that the most important predictors of long-term annoyance were negative expectations of changes to the sound source, fear of the sound source, and the actual sound exposure level (beta coefficients 0.33, 0.37, and 0.25, respectively). Beta coefficients are results of statistical

regression analyses that give an idea of how sensitive annoyance is to changes in the relevant predictor. Higher beta values mean that annoyances changes more with changes in that predictor than with others predictor variables.

The two non-acoustical variable studies also show that interference with relaxation, eating, watching TV, or listening to the radio is more related to annoyance than interference with conversations. The noise level proposed in the Levels Document does not account for the importance of non-auditory activities. Despite this newer understanding, it is hard to assess levels of environmental noise with these factors in mind because there is no easy way to quantify attitudinal differences in a study population, and these factors may change in different study populations and over time (Schreckenber, Schuemer, 2010; Bartels, Marki, Muller, 2015). However, with more data and surveys that address these complicated variables, a better understanding of their importance to the annoyance response will be obtained.

2.3.4 Summary and Research Gaps

The Levels Document specified that annoyance from environmental noise exposure was mostly caused by activity interference, specifically speech interference. The Levels Document discussed a number of annoyance studies and used results from three studies on aircraft noise annoyance at nine airports to calculate a prediction for the annoyance impact at the proposed level to protect against speech interference. While the studies used in this analysis were influential at the time, there were a number of simplifications and conversions to the data used that make the prediction dubious. Overall, the authors of the Levels Document did not feel there was substantial evidence available to determine a level requisite to protect against annoyance.

As described in the annoyance exposure-response model, some aspects of an annoyance response to noise can be measured and observed objectively and quantitatively, while others are complex social and attitudinal differences between participants and regions that are often subjective and self-reported.

Despite the wealth of annoyance survey data available, there are large discrepancies in correlations derived from different data sets. Percent highly annoyed can range from 10% to 70% in different studies at the same noise exposure level. The large range may be caused by various non-acoustic effects like attitudinal differences or age range of the study population. Some studies have given a better idea of which non-acoustical factors are more important in predicting an annoyance response.

Research gaps include controlling for or quantifying the effect of confounding, non-acoustic variables in annoyance studies. Studying distributions of confounding variables both within study populations and across multiple studies will provide a better understanding of their overall effect. Systematic corrections for non-acoustical factors may also be studied in an attempt to reduce variance in the study data through more focused survey questions or annoyance rating scales. Another way to control for these confounding factors is to perform similar studies in the same region over longer periods. Differences in culture and general environment can be controlled for in this way.

An additional area where more research is needed is in the use of alternate or multiple metrics to describe the source of noise. While L_{dn} is useful for describing long-term annoyance from cumulative noise exposure, it fails to capture qualities of the sound that may play a part in the annoyance exposure-response relationship. Correlations of percent highly annoyed to other metrics may give smaller ranges

in percent highly annoyed at certain noise levels and may be more representative of the exposure-response model described previously.

Another major research gap is the lack of U.S. annoyance surveys performed after the 1980s. The most recent published syntheses and research have been done exclusively on foreign study populations, and the results are difficult to extrapolate to the U.S. This gap is currently being addressed by the Federal Aviation Administration in a nationwide mail and telephone survey. While the results of this survey are not yet published, they are expected to update the exposure-response curves informing the FAA's consideration of national policy on aviation noise.

2.4 Health and Sleep Impacts

2.4.1 How the Levels Document Addressed Health and Sleep Impacts

The Levels Document assumed that protection against noise-induced hearing loss is sufficient for protection against other health effects of noise. The document stated, "At this time, there is insufficient scientific evidence that non-auditory diseases are caused by noise levels lower than those that cause noise-induced hearing loss" (p. 22).

The Levels Document identified potential pathways for non-auditory health effects of noise, although it noted that a causal link had not yet been established. It stated, "Noise of lesser amplitude than that traditionally identified for the protection of hearing causes regular and dependable physiological responses in humans. Similar noise-induced physiological changes in sensitive animals regularly leads to the development of stress-related disease. The implications of generalizing from these animal studies to humans is not clear" (Appendix E, p. 210).

The Levels Document mentioned several physiological changes caused by noise, but noted that the link between these effects and long-term health had not been established. These physiological impacts include:

- Pain in the auditory system, change in balance, and startle reflex (caused by intense, very loud noise typically only found in occupational settings);
- Sleep interference;
- Fatigue, irritability, or insomnia;
- Stress; and
- Cardiovascular system impacts (vasoconstriction of the peripheral blood vessels and pupillary dilation)

Regarding sleep specifically, the Levels Document provided a theory that protecting against outdoor speech interference would also protect against sleep interference. It states, "[M]aintenance of this [55 dB L_{dn}] outdoor level will provide an indoor L_{dn} of approximately 40 dB with windows partly open for ventilation. The nighttime portion of this L_{dn} will be approximately 32 dB, which should in most cases, protect against sleep interference" (p. 39).

Since the Levels Document was published, additional research has been conducted to establish the relationship between noise exposure and negative health effects, particularly around sleep disturbance and cardiovascular impacts. This research is summarized below.

2.4.2 Current State of Research

In the last several decades, much research has been done on the effects of noise exposure on sleep disturbance and cardiovascular and metabolic health. Significant advancements in the understanding of the effect of noise on sleep have been made. There is less evidence about the relationship between noise and adverse cardiovascular outcomes, and a great deal of ongoing research in this area.

2.4.2.1 Sleep Impacts

Nighttime noise can disrupt sleep, either by making it difficult to fall asleep or by causing people to wake up during the night. Whether or not an individual's sleep is disrupted depends on individual characteristics such as noise sensitivity or age, noise exposure levels, and situational factors such as sleep stage (see Figure 13). Noise is one of many factors that can disrupt sleep; other factors include health conditions like sleep apnea, or work or family commitments that limit sleep duration.

Sleep is critical to many aspects of human health, including cognitive performance, memory, metabolism, immune and hormone function, and cardiovascular system (Watson et al, 2015). Sleep disturbance or curtailed sleep may lead to short-term effects, such as drowsiness and decreased performance. If chronic sleep disturbance occurs, it can lead to long-term health effects, including negative cardiovascular outcomes (Basner and McGuire, 2018).

The negative health impacts of sleep disruption and curtailment have been well documented in epidemiological studies (for example, see Watson et al, 2015; Somers et al, 2008). Therefore, this literature review focuses on the relationship between noise exposure and sleep disturbance rather than the impacts of sleep disturbance itself.

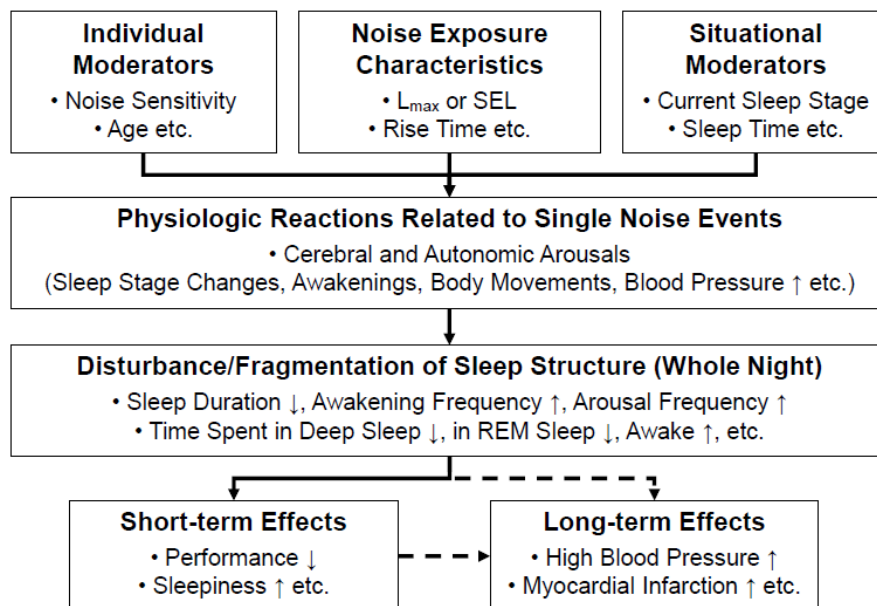


Figure 13: Summary diagram of the effects of noise on sleep. The dashed lines indicate the health consequences that may develop if sleep is disturbed by noise over long periods. (Source: Figure 1 from Basner and McGuire 2018).

Studies that investigate the impact of noise on sleep attempt to isolate the impact of noise by comparing similar populations exposed to different noise levels or by controlling for potentially confounding factors at the individual level. Studies on the effects of noise exposure on sleep typically use one of several methodologies for measuring sleep and sleep disturbance: polysomnography, actigraphy, signaled awakenings, and questionnaires. Basner and McGuire (2018) describe these methods based on relevant literature:

- *Polysomnography* is considered the “gold standard” of sleep measurement. It involves the simultaneous measurement of brain electric potentials, eye movements, and muscle tone in 30-second increments throughout the night. Polysomnography is the only method that allows for the measurement of sleep stages and sleep structure. However, it requires specialized personnel to attach and detach the electrodes and visually score sleep stages. This limits the sample size of studies that use polysomnography.
- *Actigraphy* infers sleep or wake from wrist movements measured with a watch-like device that is typically worn for 24 hours. These devices are now available on the consumer market, but unlike polysomnography do not provide information on sleep stages.
- *Signaled awakenings* involve participants pressing a button when they wake up during the night. A challenge with this approach is that it requires participants to wake up and be motivated to press a button, so may be less accurate than methods that do not rely on people to take an action.
- *Questionnaires* or surveys are used to ask about past awakenings or other aspects of sleep quality, and may refer to one night or longer periods. These subjective assessments of sleep do not always agree with objective measurements. In addition, when a question asks specifically about a noise source it may bias the responses.

The studies on noise exposure and sleep reviewed as part of this literature review were meta-analyses that analyzed two types of studies: those that used polysomnography to estimate the noise level at which someone would be awakened, and those that used surveys on self-reported sleep disturbance.

Measuring Awakenings

One of the most comprehensive recent studies on the connection between noise and sleep was conducted by the World Health Organization in 2018 (Basner and McGuire). The study involved a systematic review of 74 articles published between 2000 and 2015 on the effects of environmental noise exposure on sleep. The study involved a pooled analysis of polysomnographic studies on the acute effects of transportation noise on sleep. It also included a meta-analysis of questionnaires linking road, rail, and aircraft noise exposure to self-reports of sleep disturbance (that portion of the study is described in the Self-Reported Sleep Disturbance section below).

For the pooled analysis, the authors estimated the effect of noise on sleep disturbance by calculating both an unadjusted model and a model that was adjusted for age, gender, weekday, and time from sleep onset. They used the unadjusted model to derive exposure-response relationships between noise levels and the probability of awakening. These exposure-response relationships are shown in Figure 14. The study found that for a noise level of 55 dB ($L_{AS,max}$), the probability of an additional awakening or

change to sleep stage 1 (S1) in a 90-second window after the noise event was approximately 5 percent for road, aircraft, and rail noise.

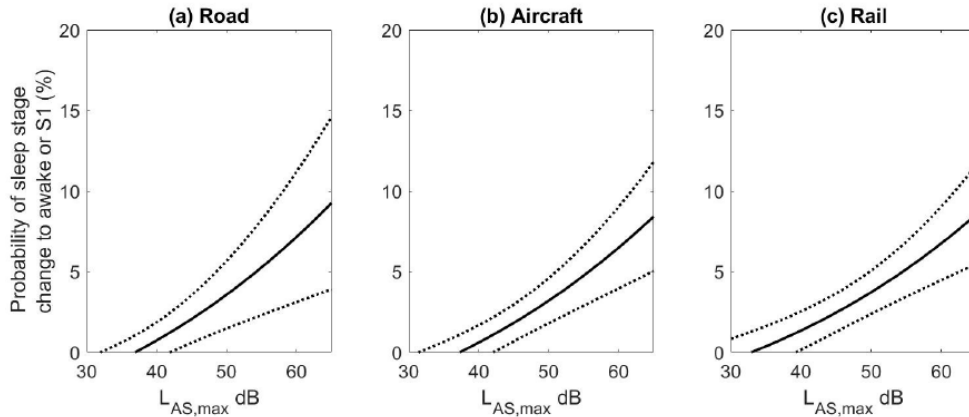


Figure 14: Basner and McGuire functions showing the probability of additional sleep stage changes to awake or S1 in a 90-second time window following a noise event depending on the maximum indoor sound pressure level ($L_{AS,max}$). Dashed lines indicate 95% confidence intervals. The results shown are for the three unadjusted models based on transportation noise source. Source: Figure 6 from Basner and McGuire 2018.

Self-Reported Sleep Disturbance

The Basner and McGuire study also involved a meta-analysis of surveys that used self-reported sleep outcomes. The authors used data from the studies reviewed to derive exposure-response relationships for the percent highly sleep disturbed for the different sleep outcome measures: awakenings from sleep, difficulty falling asleep, and a combined estimate. Since each of the studies in the meta-analysis asked different questions about sleep disturbance and had different response options, the authors calculated a binary variable for highly sleep disturbed based on the data in the individual studies reviewed. They categorized respondents as highly sleep disturbed if they chose the top two ratings for sleep disturbance on a 5-point scale (top 40%) or the top three ratings on an 11-point scale (top 27%), or if they reported symptoms of sleep disturbance three or more times per week.

For L_{night} between 40 and 65 dB, the meta-analysis found a statistically significant association between noise exposure and sleep disturbance when the noise source was mentioned in the question. These exposure-response relationships are shown in Figure 15. In general, respondents reported higher sleep disturbance (both falling asleep and awakenings) for aircraft noise than for equivalent levels of road and rail noise. When the noise source was not specifically mentioned, for most of the sleep measures and noise sources there was an association between noise and sleep disturbance, but these associations were not statistically significant. The authors note that this indicates that the context or wording of the questions could bias the results. In this case, directing someone's attention to a noise source may make it more likely that they will say that this noise source disrupts sleep.

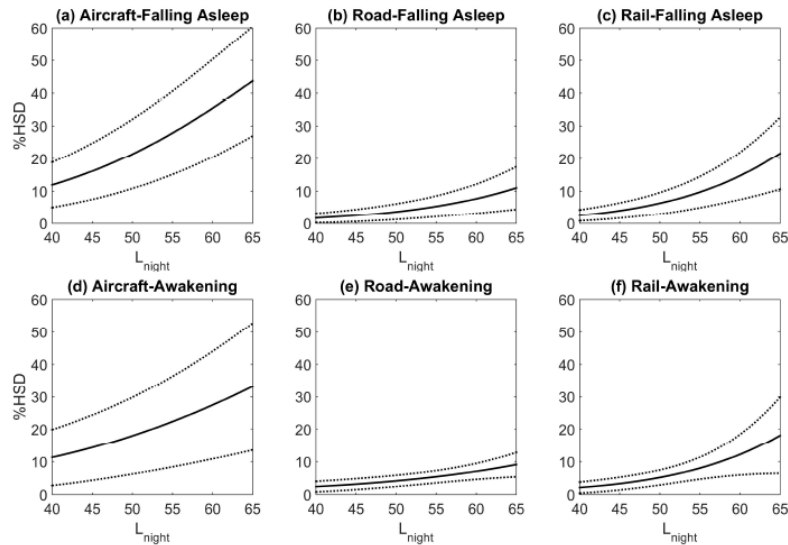


Figure 15: Basner and McGuire functions showing the percent highly sleep disturbed (HSD) based on responses to questions on awakenings or difficulty falling asleep for road, rail, and aircraft noise. The graphs are for studies that asked about how noise affects sleep, and the dashed lines are 95% confidence intervals (Source: Figure 7 from Basner and McGuire 2018).

The exposure-response models in Figure 15 allow for the estimation of the percentage of people who are expected to be highly sleep disturbed at different noise levels. For example, when the noise source was mentioned in the question, the percentage of study participants that were highly sleep disturbed for L_{night} levels of 45 dB of road noise was approximately 3 percent, while for rail noise that figure was 3.3 percent. For aircraft noise, approximately 15 percent of the study population was estimated to be highly sleep disturbed for the same noise level. While the article does not provide an explanation for why the percentage highly sleep disturbed was higher for aircraft than for other noise sources, this may be due to either the characteristics of aircraft noise or to people's reactions to the noise. People perceive intermittent noise like aircraft flyovers differently than constant noise such as road traffic, even though the average noise (L_{night}) may be the same. This intermittent aircraft noise may cause more sleep disturbance, or people may report being more sleep disturbed because they are annoyed by aircraft flyovers (see the Annoyance section 3.3). In addition, aircraft noise has more high frequency tones than other noise sources, and aircraft pass overhead, which could cause people to perceive danger and awaken.

The meta-analysis used by Basner and McGuire was similar in methodology to a previous study conducted by Miedema and Vos (2007). That study involved a re-analysis of pooled data from studies on the association between self-reported sleep disturbance and exposure to nighttime transportation noise. Since the studies reviewed used different scales for sleep disturbance, the authors translated the results into a scale of 0-100, based on the assumption that a set of sleep disturbance categories divides this range into equally spaced intervals. Based on this 100 point scale, Miedema and Vos categorized sleep disturbance as follows:

- 72.01-100: Highly sleep disturbed
- 50.01-72: Sleep disturbed
- 28.01-50: At least a little sleep disturbed

The authors then developed functions for the percentage of people who were highly sleep disturbed for different L_{night} levels between 45 and 65 dB (see Figure 16). These functions show that at the same average nighttime noise-exposure level, aircraft noise is associated with more self-reported sleep disturbance than road traffic, and road traffic noise is associated with more sleep disturbance than railways. For example, at an L_{night} of 45 dB approximately 3.6 percent of the participants reported being highly sleep disturbed from road noise, while 2.3 percent were highly sleep disturbed from rail noise, and 4 percent were highly sleep disturbed from aircraft noise.

While the estimates for disturbance from road and rail noise in Miedema and Vos are similar to Basner and McGuire, the percent highly sleep disturbed from aircraft noise was more than 10 percentage points lower at all noise levels studied. Basner and McGuire suggest several potential reasons for these differences.

The studies used different methodologies to derive the models and reviewed different studies as part of the meta-analysis. For example, Basner and McGuire included several studies from Japan and South Korea, where attitudes towards noise could be different from Europe. In addition, Miedema and Vos looked at studies conducted between 1971 and 2004, while Basner and McGuire looked at studies from the year 2000 or later. Recent updates to annoyance exposure-response curves have found an increase in annoyance for aircraft noise, but not for other noise sources (see Annoyance section 3.3); this increase in annoyance could also present itself as an increase in self-reported sleep disturbance.

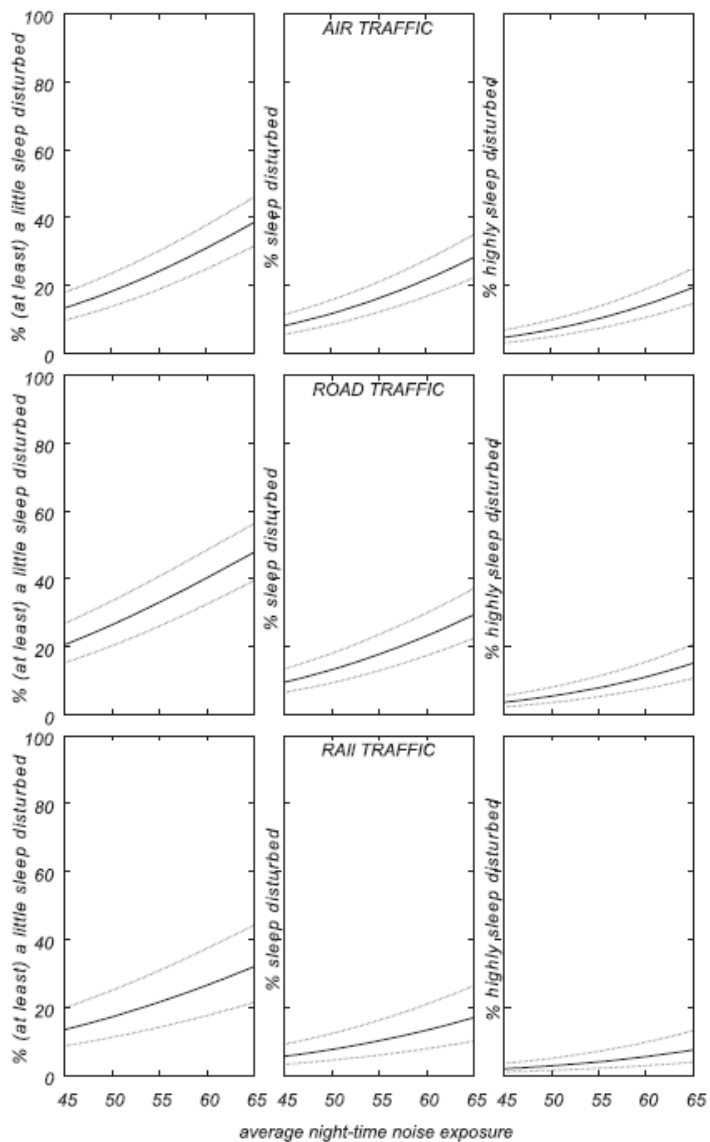


Figure 16: Functions showing sleep disturbance measures in relation to the average nighttime exposure outside at the most exposed façade. The dashed lines show 95% confidence intervals. (Source: Figure 1 from Miedema and Vos 2007).

The Miedema and Vos study also looked at the age of respondents and found that the association of noise-induced sleep disturbance with age has an inverse U-shape, with the strongest reaction found between 50 and 56 years of age, and lower effects at both younger and older ages. The authors suggest that the lower effect of noise at higher ages may be because hearing capacity declines with age. However, they note that this does not explain the lower effect of noise at younger ages or the inverted U-shape of the data, and suggest that it may be due to age-related changes to the way the brain processes information.

2.4.2.2 Cardiovascular and Metabolic Impacts

Noise can lead to adverse cardiovascular health outcomes by disrupting sleep and/or causing stress. Studies on the impact of noise on cardiovascular health look at different health outcomes. These include hypertension, ischemic (coronary) heart disease, and stroke. Metabolic outcomes such as diabetes and obesity have also been studied.

Research on the connection between noise exposure and cardiovascular impacts typically involves observational studies that look for associations between the occurrence of disease and the exposure to noise at a population or individual level. Since these observational studies do not include a randomized control group, they aim to demonstrate associations rather than trying to establish causation. These studies may be:

- cross-sectional studies (measures health outcomes in a population at a period in time);
- cohort studies (following a group within a population for a specified period of time); or
- case control studies (retrospective studies that compare cases who have a certain condition with a control group known not to have developed the outcome of interest) (Coggon et al).

Ecological studies, which compare outcomes at the population or community level rather than the individual level, are also used.

Van Kempen et al (2018) conducted a literature review of studies on the association between cardiovascular and metabolic outcomes and noise exposure by evaluating 61 studies across different health outcomes and transportation noise sources. The authors calculated the change in health metric (relative risk, blood pressure change, or change in body mass index or waist circumference) per 10 dB (L_{DEN}) noise level increase for each noise source (air, road, and rail traffic) and health outcome (risk of hypertension, ischemic heart disease, stroke, diabetes, and obesity). It also ranked the quality of the evidence for the association between the noise source and health outcome using a modified version of the GRADE criteria (see Table 7).⁹

⁹ For more information on GRADE to rate quality of evidence and strength of recommendations, see: <https://www.bmj.com/content/336/7650/924>.

Table 7: The levels of quality of evidence of the GRADE system (Source: Table 1 from Van Kempen et al 2018)

Quality of Evidence	Definition	Examples of When This is the Case
High	Further research is very unlikely to change our confidence in the estimate of effect	Several high-quality studies with consistent results
Moderate	Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate	One high-quality study or several studies with some limitations
Low	Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate	One or more studies with severe limitations
Very Low	Any estimate of effect is very uncertain	No direct research evidence One or more studies with very severe limitations

The authors applied the GRADE criteria to each of the individual articles, as well as to the overall findings for each combination of noise source and health outcome. Although many of the individual studies reviewed found statistically significant associations between noise exposure and cardiovascular outcomes, for most of the summary findings the authors ranked the quality of evidence as low using the GRADE criteria (see Table 8), indicating that future research is likely to change the findings. The authors rated the quality of evidence as low largely due to study designs (e.g., mostly ecological and cross-sectional studies rather than more robust case-control or cohort studies), limited number of studies on the topic, or conflicting results between studies. The strongest evidence was for the association between road traffic and ischemic heart disease (IHD), which the authors rated as moderate. For this association, the studies reviewed indicated that the risk of IHD increases continuously for road traffic noise levels from about 50 dB L_{DEN}. The relative risk of the incidence of IHD per 10 dB L_{DEN} was 1.08 within the range of 40-80dB.¹⁰ Compared with cardiovascular outcomes, Van Kempen et al found fewer studies that looked at the impact of noise on the metabolic system (diabetes and obesity), and the results were not consistent. The authors state that it is too early to draw connections about the impact of noise on the metabolic system.

¹⁰ The relative risk is the ratio of the probability of an event occurring in an exposed group compared with the probability of it occurring in a non-exposed group.

Table 8: Summary of findings from Van Kempen et al 2018.

Health outcome	Noise source	Number of studies reviewed	Quality of evidence supporting association between noise source and health outcome
Hypertension	Air traffic	10	Very low
	Road traffic	27	Very low
	Rail traffic	6	Very low
Ischemic heart disease (IHD)	Air traffic	7	Low
	Road traffic	19	Moderate
	Rail traffic	4	Very low
Stroke	Air traffic	7	Low
	Road traffic	6	Low
	Rail traffic	1	Low
Diabetes	Air traffic	2	Low
	Road traffic	3	Low
	Rail traffic	2	Low
Obesity	Air traffic	2	Low
	Road traffic	6	Low
	Rail traffic	4	Low

Another recent literature review (Peters et al, 2018) focused on aviation noise and cardiovascular impacts. This study involved a review of 17 studies on aircraft noise and cardiovascular impacts that were published between 2013 and 2017. Sixteen of the studies were based in Europe, and one was based in the U.S. The literature review found that the studies generally report statistically significant associations between aircraft noise and a range of adverse cardiovascular outcomes. In particular, adverse cardiovascular outcomes were found to have statistically significant associations with nighttime aircraft noise exposure. The associations between aircraft noise and cardiovascular outcomes were stronger in subgroups either that were more highly exposed to aircraft noise or that had risk factors for adverse cardiovascular outcomes. The article also suggests areas for further research, which are described in the Research Gaps section below.

In the U.S., the largest recent study on the impact of transportation noise on cardiovascular outcomes involved a study of aviation noise across 89 airports (Correia et al, 2013). The study used a dataset of Medicare billing claims information of 6 million adults over age 65 living near airports, and noise contours of outdoor L_{dn} provided by the FAA (starting at 45dB).¹¹ The health outcomes studied were hospital admissions for cardiovascular disease, including heart failure, heart rhythm disturbances, cerebrovascular events, ischemic heart disease, and peripheral vascular disease. The study used two types of statistical analysis to determine the effect of noise on cardiovascular outcomes. First, the authors used a hierarchical Poisson regression model to calculate the percentage increase in the zip code level hospital admission rate associated with a 10 dB increase in the zip code level aircraft noise (within the 45 dB contour and higher). They also adjusted for potential confounding variables, including

¹¹ The noise contours were based on results modeled in FAA's Integrated Noise Model version 7.0a (2007).

socioeconomic status (specifically percentage Hispanic and median household income) and air pollution (zip code level fine particulate matter [PM_{2.5}], ozone concentrations, and road density). Based on this analysis, the study found that across all of the airports in the study, a zip code with a 10 dB L_{dn} higher noise exposure had a 3.5% higher cardiovascular hospital admission rate.

This study also investigated the evidence of a potential non-linear association between exposure to aircraft noise and hospital admission. The authors studied this by replacing the aircraft noise exposure variable (originally defined as a continuous variable) with a categorical variable indicating low, medium, or high exposure to aircraft noise (50 dB or less, 50-55 dB, and higher than 55 dB). Based on this analysis, the study found evidence of a threshold for the effect of noise on cardiovascular hospital admissions. It found consistent statistically significant associations in only the highest exposure group (>55 dB).

2.4.2.3 Intervention Studies

Another category of studies on the relationship between noise and health looks at how health outcomes compare before and after an intervention to reduce noise. Brown and Van Camp (2017) conducted a literature review of studies from 1980 to 2014 on evidence of the effects of transportation noise interventions (for aircraft, road, and railroad noise) on human health. They categorized the interventions as shown in Table 9 below.

Table 9 Noise Interventions (Source: Brown and Van Camp 2017 Table 1)

Intervention Category	Intervention Sub-Category	Examples
Source interventions	change in emission levels of sources	motor vehicle emission regulation; rail grinding; road surface change; change in traffic flow on existing roadways/ railways; change in number of aircraft flights
	time restrictions on source operations	airport curfew, heavy vehicle curfew
Path interventions	change in the path between source and receiver	noise barrier
	path control through insulation of receiver's dwelling	insulation of building envelope
New/closed infrastructure	opening of a new infrastructure noise source, or closure of an existing one	new flight path; new railway line; new road bypass; or closure of any of these
	planning controls ² between (new) receivers and sources	urban planning control; 'buffer' requirements ²
Other physical interventions	change in other physical dimensions of dwelling/ neighbourhood	availability of a quiet side; appearance of the neighbourhood; availability of green space
Education/communication interventions	change in behaviour to reduce exposures; avoidance or duration of exposure	Educating people on how to change their exposure
	community education, communication	Informing people to influence their perceptions regarding sources, or explaining reason for noise changes

The analysis of studies in the literature review showed that many of the interventions were associated with improvements in health outcomes irrespective of the source type, intervention type, or outcome measured. For road noise, the authors found evidence in the studies reviewed of a statistically

significant association between three types of interventions (path, new/closed infrastructure interventions, and other physical) and reduced sleep disturbance. One of the studies reviewed evaluated a source intervention on sleep disturbance from road traffic noise, but it did not find a statistically significant effect. The study also found evidence of an association between other physical interventions and cardiovascular effects. For aircraft noise, they found evidence of an association between new/closed infrastructure and reduced sleep disturbance. None of the studies reviewed looked at other types of interventions and sleep disturbance for aircraft noise. Similarly, none of the studies reviewed looked at the sleep disturbance or cardiovascular effects of rail noise.

Despite numerous studies finding associations between different noise interventions and health outcomes, the authors found that there was not enough evidence to compare health outcomes across interventions to determine which interventions are most effective. This was because there were many possible combinations of noise source, health outcome, and intervention type, and most of the combinations did not have more than several studies. There was also no clear evidence about the threshold of noise exposure change needed to result in a change in health outcome.

2.4.3 Summary and Research Gaps

The Levels Document assumed that protection against noise-induced hearing loss is sufficient for protection against other health effects of noise. Since the Levels Document was published, there has been substantial research on the connections between noise and sleep and noise and cardiovascular outcomes. It is now well understood that noise levels lower than those necessary to cause hearing loss (i.e., 70 dB $L_{Aeq(24)}$ per the Levels Document) can lead to other negative health outcomes including disrupted sleep and adverse cardiovascular outcomes.

Numerous studies have found a statistically significant association between noise exposure and sleep disturbance or curtailment, across all transportation noise sources. Sleep disruption can lead to both short and long term physiological impacts. Studies have used polysomnography to determine the noise level that is likely to awaken someone. A recent pooled analysis by Basner and McGuire (2018) indicates that at a noise level of $L_{AS,max}$ 55 dB, the probability of an additional awakening or change to sleep stage 1 (S1) in a 90-second window after a noise event is approximately 5 percent for road, aircraft, and rail noise. However, waking up once due to noise does not necessarily mean that an individual will feel disturbed by the noise or experience negative physiological effects.

Many studies have used questionnaires to establish exposure-response relationships between noise exposure and self-reported sleep disturbance. Meta-analyses of these studies (Basner and McGuire 2018; Miedema and Vos 2007) indicate that for a given noise level, self-reported sleep disturbance is higher for aircraft noise than for road or rail noise. For a nighttime noise exposure (L_{night}) of 45 dB, approximately 2-4 percent of respondents report being highly sleep disturbed from road or rail noise. These studies differed on the percentage of people highly sleep disturbed from aircraft noise, with a range of 4-15 percent at 45 dB. While most research studies of sleep disturbance or nighttime noise use cumulative metrics such as L_{dn} or L_{night} , further research is needed to determine whether the cumulative impact of noise or the effects of single noise events predominate in characterizing sleep disturbance.

As devices that use actigraphy to measure sleep based on wrist movements are becoming more widely available on the consumer market, there is an opportunity to use the data generated by these devices to further study the connections between sleep and noise and to complement other methodologies such as polysomnography and questionnaires. An advantage of actigraphy is that it allows for data collection from larger numbers of people than polysomnography. Future work will be needed to manage and analyze this crowd-sourced data and to determine if the relationships between noise and sleep derived from actigraphy are similar to those from other forms of sleep measurement.

The evidence for the relationship between noise exposure and adverse cardiovascular and metabolic outcomes is more limited. Although individual studies have shown a statistically significant association between noise exposure and adverse cardiovascular outcomes, there is not consistent evidence across studies for all noise sources and cardiovascular outcomes. The most consistent findings are for the association between ischemic heart disease and road traffic noise, where a recent meta-analysis found that the risk of IHD increases continuously for road traffic noise levels from about 50 dB (L_{DEN}) (Van Kempen et al, 2018). The evidence for the effect of noise on metabolic outcomes is even more limited.

Many of the studies on noise and cardiovascular and metabolic outcomes use cross-sectional or ecological study designs rather than the more robust methods of cohort studies and case control studies. There have also been a limited number of these studies conducted in the U.S., particularly on a large scale. Further research is needed to more definitively establish the relationship between noise exposure and cardiovascular and metabolic outcomes, and the noise levels at which these outcomes are experienced.

Another area for further research includes determining the noise metrics that are most predictive of cardiovascular outcomes (Peters et al, 2018). Similar to sleep disturbance, most studies of cardiovascular use L_{dn} , L_{Aeq} , or similar metrics that average noise across the day and/or night. However, further research is needed to determine whether these metrics or metrics that focus on the effects of intermittent noise sources should be used.

In addition, the effects of noise on health may not be evenly distributed across a population. Age, other health conditions, or socioeconomic status may all affect how an individual reacts to a given noise exposure. Further research is needed to determine how the association between noise exposure and health changes across different subgroups (Peters et al, 2018).

On the topic of interventions to reduce noise, further research is needed to determine the relative impacts of different interventions on sleep disturbance and health outcomes, across all noise sources. If this research concludes that certain interventions have a greater health benefit for the same amount of noise reduction, these interventions could be encouraged.

2.5 Cognitive Effects

This section describes research on the effects of noise on children's learning, cognitive development, and cognitive performance. Research on this topic has examined a variety of cognitive outcomes, including reading comprehension, long and short-term memory, and standardized test scores. This section discusses the effects of environmental noise on cognition in children of varying ages, although most of the studies focus on elementary school-aged children.

2.5.1 How the Levels Document Addressed Cognition

The Levels Document discussed recommended noise levels to protect public health and welfare in different settings, including educational settings (classrooms, school buildings, and school grounds not used for athletics). The primary consideration for determining these levels is the prevention against activity interference, and in particular speech interference.

The Levels Document recommended the following levels for educational facilities:

- To prevent against activity interference: $L_{eq(24)}$ of 45 dB indoors, and $L_{eq(24)}$ of 55 dB outdoors (the document states that it provides the outdoor levels because teaching will sometimes occur outside the school building).
- To prevent against hearing loss: $L_{eq(24)}$ of 70 dB for both indoors and outdoors. The document notes that an $L_{eq(8)}$ of 75 dB may be acceptable as long as the exposure over the remaining 16 hours per day is low enough to result in a negligible contribution to the 24-hour average, i.e., no greater than an L_{eq} of 60 dB.

The Levels Document did not discuss the possibility that noise could affect children in schools in ways other than activity interference or hearing loss (e.g., through distraction or other cognitive impacts).

2.5.2 Other Guidelines for Noise Levels at Schools

The 1999 *WHO Guidelines for Community Noise* set recommendations for children's environmental noise exposure in school playgrounds and classrooms that differ slightly from the Levels Document in purpose and levels. The Guidelines stated:

- School playgrounds should not exceed 55 dB L_{Aeq} during play to protect against annoyance.
- School classrooms should not exceed 35 dB L_{Aeq} during class to protect against speech intelligibility and disturbance of information extraction.

Recent analyses (Clark and Paunovic, 2018) have noted that 35 dB L_{Aeq} is a very low level of noise exposure and considered unachievable by some. The *WHO Environmental Noise Guidelines for the European Region* were updated in 2018, but do not provide specific recommendations for school environments.

2.5.3 Current State of Research

Since the Levels Document was published, additional research has been conducted on the impact of noise on cognition. The sections below describe theories on the pathways through which noise affects cognition, research on noise at school and cognition, and research on noise at home and cognition. Overall, there is evidence that aircraft noise exposure negatively affects children's learning, but there is limited information available for other noise sources.

2.5.3.1 How Noise Affects Cognition

Noise can affect children's learning in several ways. First, noise can impair speech communication and listening comprehension (Clark and Paunovic, 2018; Klatt et al 2013). Speech interference is of particular concern for school environments because if children cannot hear fully in school it is more difficult for them to learn. In addition, children have more difficulty understanding speech in noisy

conditions than adults do. One explanation for this is that children have less developed vocabularies, so they do not have the same ability as adults to use stored phonological knowledge or context clues to reconstruct words that are masked by noise (Klatte et al. 2013). Children also have less developed attention skills, which makes it harder for them to focus on speech if background noise is present (Klatte et al. 2013). For a more detailed discussion of the noise levels to protect against speech interference, see Section 2.2, Activity Interference.

Beyond speech interference, noise can affect children’s learning and cognition by affecting memory, attention, and stress. Memory may be affected because irrelevant sounds are directly incorporated into working memory, interfering with relevant information (Klatte et al, 2013). Noise can also capture a child’s attention, which may keep them from remembering important information (Klatte et al, 2013). In loud environments students may also “tune out” noise, a strategy that they may over-generalize by tuning out information important to learning as well (Clark and Paunovic, 2018). Additionally, noise exposure can lead to annoyance, which can cause physiological and psychological stress responses, affecting a child’s ability to concentrate and learn effectively, as well as their mood (Clark and Paunovic, 2018). Finally, many students who go to school in loud areas are also affected by noise at home, which can disrupt their sleep (Clark and Paunovic, 2018). As described in the Health and Sleep Impacts section, sleep disturbance can hinder memory, performance, and other factors that could affect learning.

2.5.3.2 *Noise and Cognition in School Environments*

A recent meta-analysis of studies on the relationship between noise and cognition (Clark and Paunovic, 2018) was conducted in support of the new WHO *Environmental Noise Guidelines for the European Region*. The authors reviewed 34 papers on noise and children’s cognition, and evaluated the strength of the evidence using the GRADE methodology (see the Health and Sleep Impacts section for a description of the GRADE methodology). The majority (74%) of the studies evaluated aircraft noise, while 32% looked at road noise. Only 9% of the studies evaluated rail noise, and 9% evaluated combined noise sources.¹² The majority of the studies used a cross-sectional design, while fewer used more robust study designs such as longitudinal studies (looking at the same population over time) or intervention studies (measuring cognition before and after a change in noise levels). The studies looked at various outcomes of cognition and learning, including reading and oral comprehension, memory, attention, impairments assessed through standardized assessments such as the SAT, and executive function deficit.

Table 10 summarizes key findings from Clark and Paunovic on the effects of environmental noise on cognition across different noise sources and cognition outcomes, as well as their assessment of the quality of evidence. The authors found that there was moderate quality evidence for a harmful effect of aircraft noise on reading and oral comprehension, standardized assessment tests, and long- and short-term memory. There was also moderate quality evidence for a harmful effect of railway noise on standardized assessment tests. The authors rated all other combinations of noise sources and cognition outcomes as having low or very low quality evidence. They note that this does not mean that the individual studies themselves were of low quality, but rather the overall evidence across the studies was of low quality. Many of the individual studies showed significant effects, but the overall evidence was

¹² Since some of the studies considered multiple noise sources, the percentages add up to over 100%.

rated low because of a limited number of studies, conflicting findings across studies, or the methodology of particular studies (e.g., cross-sectional design rather than methods that are more robust).

Table 10: Summary of quality of the evidence and assessment of effect for environmental noise effects on cognition (Table 2 from Clark and Paunovic 2018).

Cognitive Domain	Environmental Noise Exposure		
	Aircraft Noise: Quality of Evidence & Assessment of Effect	Road Traffic Noise: Quality of Evidence & Assessment of Effect	Railway Noise: Quality of Evidence & Assessment of Effect
Reading and oral comprehension	Moderate quality—harmful effect	Very low quality—no effect	n.a.
Standardized assessment tests	Moderate quality—harmful effect	Very low quality—harmful effect	Moderate quality—harmful effect
Long-term and short-term memory	Moderate quality—harmful effect	Very low quality—harmful effect	Very low quality—harmful effect
Attention	Low quality—no effect	Very low quality—no effect	Very low quality—no effect
Executive function	Very low quality—no effect	Low quality—no effect	n.a.

n.a. no studies available to evaluate.

Several large-scale studies of the impact of noise on cognition in children have been conducted in recent years. Although many of these were included in the Clark and Paunovic review, the information in the individual studies provides additional details on the relationships between noise and cognition, and as such are described in more detail here. The RANCH study was a cross-national, cross-sectional study of nearly 3,000 children aged 9-10 attending 89 schools near airports in the Netherlands, Spain, and the United Kingdom (Stansfeld et al., 2005). The study found statistically significant associations between exposure to chronic aircraft noise and impairment of reading comprehension and recognition memory. In particular, a 5 dB difference in aircraft noise was associated with a 2-month reading delay in the UK and a 1-month reading delay in the Netherlands (national data on reading delay was not available for Spain). In the Netherlands and Spain, a 20 dB increase in aircraft noise was associated with a decrease of one-eighth of a standard deviation on a reading test; in the UK, the decrease was one-fifth of a standard deviation (see Figure 17).

The RANCH study also found that exposure to road traffic noise was linearly associated with improvements in episodic memory, which the authors noted, was not the expected outcome and required further study. The study did not find statistically significant effects for the association between aircraft noise and impairment in working memory, prospective memory, or sustained attention, or for the association between road traffic noise and reading comprehension, recognition, working memory, prospective memory, or sustained attention.

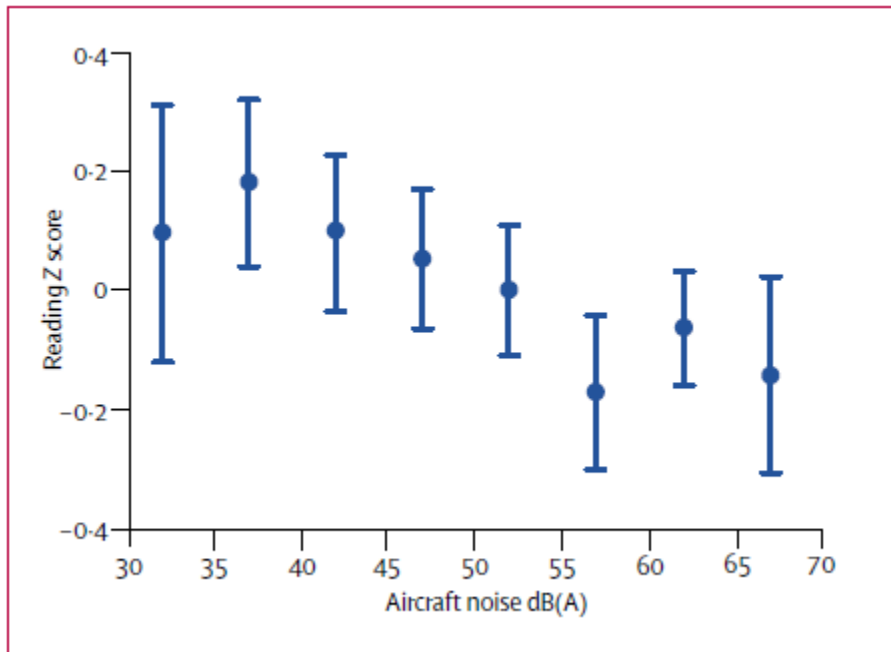


Figure 17: Adjusted mean reading Z score (with 95% confidence interval) for 5 dB bands of aircraft noise, adjusted for age, sex, and country. Figure 1 from Stansfeld et al, 2005.

In 2013, a follow-up to the RANCH study was conducted in the UK to assess the longitudinal effects of aircraft noise on children’s cognition (Clark et al, 2013). The study involved 461 children in London aged 15-16 years who had also participated in the original RANCH study. The study found that aircraft noise exposure at both primary and secondary schools was associated with poorer reading comprehension at age 15-16, but this finding was not statistically significant. The authors noted that the study’s small sample size might explain the lack of statistical significance for this finding.

Hygge et al. (2002) also evaluated the effects of aircraft noise on learning over time. The authors used the opening of a new airport in Munich, Germany and associated changes in flight patterns to conduct a before/after study of the effects of noise on cognition. 326 children (average age 10.4 years) took part in the study, and the authors measured cognitive outcomes once before the switch and twice afterwards (up to two years following the switch). The authors found that after the switch, long-term memory and reading decreased for the group newly exposed to noise near the new airport, and improved for the group formerly exposed to noise near the old airport. Short-term memory also improved for the formerly exposed group.

The NORAH study evaluated the effects of chronic exposure to aircraft noise on the cognitive performance and quality of life of schoolchildren near Frankfurt Airport in Germany (Guski et al., 2016). The study involved 1,242 children who were 8 years old from 29 schools near the airport. Cognition outcomes were studied through performance tests, in particular reading tests, and through surveys with children, parents, and teachers. The study found a significant linear association between

aircraft noise levels at school and decreasing reading performance in second graders. In particular, a one month delay in reading was observed for an increase in noise levels by 10 dB (L_{Aeq} 8:00am-2:00pm).

In the United States, the Airport Cooperative Research Program sponsored a study on the effects of aircraft noise on student performance near 46 airports (National Academies, 2014). The study found statistically significant associations between airport noise (measured as exposure to DNL of 55 dB or higher) and student mathematics and reading test scores, after controlling for demographic and school factors (such as the presence of sound insulation). The study also found that for a sample of 119 schools, the effects of aircraft noise on children’s learning were no longer statistically significant once the school installed sound insulation.

2.5.3.3 Noise at Home and Cognition

While cognition is primarily studied in school environments, several studies have evaluated the impact of noise at home on children’s cognition. One challenge with this approach is that because a child’s school is typically near their home, children who go to schools in noisy areas tend to live in noisy areas as well; therefore, it is difficult to disentangle the effects of noise at home and at school. Clark et al. (2006) analyzed RANCH study data along with data on aircraft noise exposure at home. The authors found that increasing aircraft noise exposure at home was statistically significant and linearly related to poorer reading comprehension. However, there was no additional effect of aircraft noise exposure at home after adjustment for aircraft noise exposure at school. In other words, aircraft noise exposure at home was highly correlated with aircraft noise exposure at school (see Figure 18).

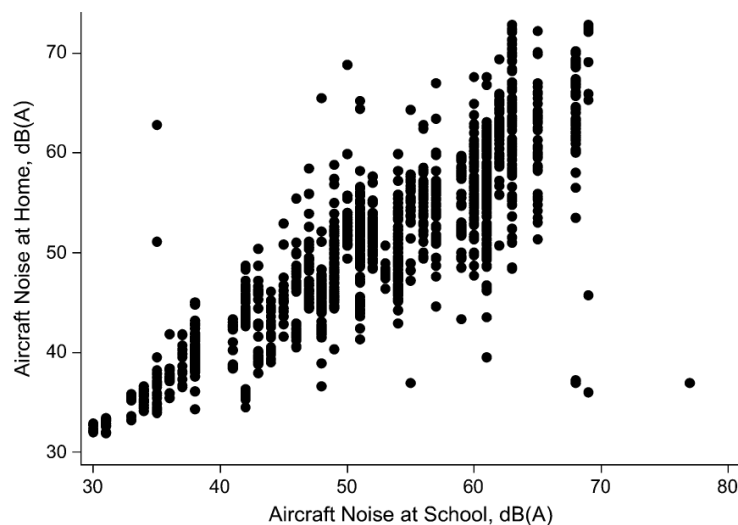


Figure 18: Association between aircraft noise exposure at home and at school, based on data from the RANCH project collection from 2001-2003 (Figure 2 from Clark et al. 2006)

Matsui et al. (2004) attempted to study the effect of noise exposure at home by finding situations where there was variation between noise at home and noise at school. The authors looked at cognition outcomes for fourth graders at 10 schools with high aircraft noise levels (16-hr outdoor L_{Aeq} >63dB) near Heathrow airport in London. Data on aircraft noise exposure levels at the children’s homes was also

collected, and ranged from under 57dB to over 66dB. The study found an association between aircraft noise exposure level at home and impairment of immediate and delayed recall of memory. This association remained even after adjusting for the noise exposure level at school. The study did not find an association between noise levels at home and reading comprehension or sustained attention.

2.5.4 Summary and Research Gaps

Since the Levels Document was published, research has established that noise disrupts children's learning not only by interfering with speech, but also by affecting memory and attention. Studies have found that there is an association between exposure to aircraft noise and impaired cognition in children, particularly around the outcomes of reading comprehension, memory, and standardized test scores (Clark and Paunovic, 2018; Stansfeld et al., 2005; Guski et al., 2016; National Academies, 2014). Studies indicate that when there is an increase in aircraft noise exposure, cognition outcomes are likely to degrade (and conversely when there is a reduction in aircraft noise exposure cognition outcomes are likely to improve) (Hygge et al., 2002; National Academies, 2014).

There have been few studies on the impacts of other noise sources (such as road, rail, and stationary noise) on cognition, and there is not enough information to establish a clear association (Clark and Paunovic, 2018). Similarly, due to the correlation between noise exposure at home and at school, it is difficult to establish the effect that noise at home has on cognition. At least one study has found an association between aircraft noise exposure levels at home and memory (Matsui et al., 2004).

Additional research is needed to further understand the connections between noise and children's learning. Longitudinal and follow-up studies of the impact of noise exposure and learning over time (similar to Clark et al., 2013) could help establish the long-term effects of noise on learning. More studies are also needed to confirm whether the associations between aircraft noise and cognition are also present for other noise sources, such as road traffic, rail, and stationary noise. In addition, the majority of studies on noise and cognition have evaluated elementary school-aged children. Additional studies with both younger children and teenagers could help broaden our understanding of the impacts of noise on learning. Finally, situations where noise levels at school and at home differ should be studied to better understand the association between noise and cognition in residential settings. If there is a significant association between noise at home and cognitive outcomes, it may be partially driven by sleep disturbance, as well speech interference or distraction.

2.6 Financial Impacts

The Levels Document did not consider financial impacts of noise. The HUD noise regulation states "environmental noise is a marketability factor which [sic] HUD will consider in determining the amount of insurance or other assistance that may be given."¹³ Monetizing the effects of noise may inform decisionmaking for developers and regulators.

2.6.1 Current State of Research and Science

Volpe selected six studies that considered the financial impacts of noise exposure. Impacts were in terms of effects of noise from various sources on apartment rents or property values.

¹³ 24 CFR §51.101 (a)(4)

Studies of the financial impacts of noise typically use a hedonic regression methodology, which estimates correlations by evaluating actual market data as a function of property characteristics and environmental factors. This methodology is considered more accurate than contingent valuation, which uses surveys to ask people their willingness to pay for different elements (Theebe 2004). However, estimates derived from hedonic regression models are highly dependent on which variables are selected and controlled for, as well as decisions made by the researcher about the form of the regression equation (Theebe 2004). Five of the six studies reviewed used the hedonic regression methodology.

Another method for studying this topic uses a natural experiment to observe changes in property values after a change in noise exposure (Almer, Boes, and Nüesch 2017). However, it is difficult to find such situations in the real world, so there are a limited number of natural experiments on this topic. One of the studies reviewed used a natural experiment.

Studies on the impact of noise on housing values typically measure the change in property values per dB increase in noise (several studies refer to this measure as noise depreciation sensitivity index, or NDSI), or they look at housing prices inside and outside of a noise contour (e.g., 65 dB).

The studies reviewed covered different transportation noise sources (aviation, roadway, and rail) and evaluated the impact of noise on apartment rents or property values. Studies were conducted over different times, but in aggregate covered data collected between 1997 and 2012. Three studies were domestic and three were from Europe. All studies found a decrease in housing prices associated with noise exposure; however, the magnitude of this discount varies. The results of these studies are summarized in Table 11 below and in the annotated bibliography.

Table 11 Impacts of Noise on Housing Values Summary of Findings

Method used	Author and date	Region studied	Transportation mode	Housing type	Noise Metric	Noise discount
Natural experiment (before and after changes in flight patterns)	Almer, Boes, and Nüesch (2017)	Zurich, Switzerland	Aviation	Apartment rents	L _{Aeq}	1.7% per dB
Hedonic regression	Theebe (2004)	Amsterdam, Netherlands	Mixed traffic noise (road, rail, aviation)	Residential property values	L _{Aeq}	0.3-0.5% per dB (over 65dB)
	Brandt and Maennig (2011)	Hamburg, Germany	Mixed traffic noise (road, rail, aviation)	Condominium listing prices	L _{den}	0.23% per dB
Hedonic regression with noise contours	McMillen (2004)	Chicago, IL	Aviation	Residential property values	L _{dn}	Over 65 dB: 9.2%
	Ozdenrol, Huang, Javadnejad, and Antipova (2015)	Memphis, TN	Road traffic	Residential property values	L _{dn}	45-50 dB: 1.6% 50-55 dB: 3.7% 55 and above: 4.3%
	Walker (2016)	Memphis, TN	Rail	Residential and commercial property values	L _{dn}	Over 65dB: 14-18%
Literature review of hedonic regression studies	Nelson (1980)	Multiple locations (literature review)	Aviation	Residential property values	Varied (literature review)	0.4 to 1.1% per dB
	Nelson (1982)	Multiple locations (literature review)	Road traffic	Residential property values	Varied (literature review)	0.4 +/- 0.23% per dB

For the two studies that used hedonic regression to measure the impact on housing prices per dB decrease in noise (i.e. used the NDSI metric), a 1dB increase in noise was associated with between 0.23 percent and 0.5 percent decrease in property values (Brandt and Maennig 2011; and Theebe 2004). This is in line with a literature review from the 1980s that found an NDSI ranging from 0.4 to 1.1 percent for aviation noise and of 0.4 +/-0.23% for road traffic noise (Nelson 1980 and 1982). A natural experiment

studying rents before and after changes in flight patterns found a 1.7 percent decrease in rents associated with a 1 dB increase in noise (Almer, Boes and Nüesch 2017).

Theebe (2004) notes that there may not be a linear relationship between noise impacts and property values, since noise is measured on a logarithmic scale. This study evaluated the NDSI for 5dB ranges rather than assuming a linear relationship. Brandt and Maennig (2011) also found that price discounts depend on the noise level, and that they are substantially lower for low levels of road noise as well as substantially higher for high noise levels than the price discounts estimated based on a linear trend.

Two of the studies that used contours to measure the impact of noise on housing prices used a 65 dB contour. The houses inside the contour had a 9.2 to 18 percent lower value compared to those outside the contour (Walker 2016; and McMillen 2004). One study looked at 45-50 dB, 50-55 dB, and over 55 dB, and found a 1.6, 3.7, and 4.3 decrease in property values, respectively (Ozdenerol et al 2015).

2.6.1 Summary and Research Gaps

While there is agreement in the research reviewed that an increase in noise is associated with a decrease in property values, there is not conclusive information about the magnitude of this effect. Even when studies use similar methodologies (e.g., hedonic regression), they study different geographic areas, housing types, and noise sources and control for different factors in the regression equation. This makes comparison between studies difficult. A detailed analysis that accounts for differences in these factors, or conducting repeatable studies with consistent study parameters could help to determine the magnitude to which noise affects housing prices.

The natural experiment methodology offers a promising approach for understanding the financial impacts of noise. However, it is challenging to find situations where it is possible to compare the same houses before and after a change in noise. Potential sources of data are environmental assessments or environmental impact statements for projects that are expected to change noise levels in a community. As researchers find opportunities to study financial impacts of noise before and after a change in noise exposure (e.g., a change in flight patterns or the installation of a noise wall), they should compare the results to results from a hedonic regression methodology to see if they are similar. This type of comparison may help to advance the state of knowledge about the most appropriate methodology for studying the financial impacts of noise.

3 Analysis of Special Noise Sources

3.1 Impulse Noise

3.1.1 Levels Document and Interim HUD Standard

The Levels Document provided a detailed overview of the characteristics of impulsive noise sources that distinguish it from continuous noise sources. Important attributes associated with impulse noise include high peak sound pressure level relative to average over the event, short duration, fast rise time, daily or other cumulative exposure to repeated impulses, individual susceptibility to inner ear damage, and the wide frequency content due to the short durations of the sound. The Levels Document provided examples of impulse noise events and their noise levels, presented in Table 12.

Table 12 Some typical values of peak SPL for impulse noise (in dB re 0.00002 N/m²) Source: Levels Document Table G-1

SPL	Example
190+	Within blast zone of exploding bomb
160-180	Within crew area of heavy artillery piece or naval gun when shooting
140-170	At shooter's ear when firing hand gun
125-160	At child's ear when detonating toy cap or firecracker
120-140	Metal to metal impacts in many industrial processes (e.g., drop-forging; metal-beating)
110-130	On construction site during pile-driving

Assessment of acceptable levels of impulse noise is based on hearing loss alone. Based on the data discussed in the Hearing Loss section, the Levels Document proposed an overall limit on impulse noise peak sound pressure level of 145 dB. This limit was identified based on temporary threshold shift data from exposure to short durations of sound (see section 2.1 on Hearing Loss for more information on temporary threshold shift). The Levels Document specified that this level applies to “isolated [impulse] events, irrespective of type, duration, or incidence at the ear.” In addition, the Levels Document recommended assessing impacts from impulse noise separately from continuous noise, despite recommendations found in international standards at the time.

For more specific limits, the Levels Document used an adjustment of a hearing loss curve published by the Armed Forces-National Research Council Committee on Hearing and Bio-Acoustics (CHABA) working group in 1968. The curve is a function of impulse duration based on a nominal exposure of 100 impulses per day. The CHABA limits were meant to protect 95% of the population from a maximum of 20 dB of NIPTS after 20 years of exposure. The authors of the Levels Document adjusted this curve to protect 90% of the population from 5 dB NIPTS. This adjustment translates to a 12 dB shift down of the CHABA curve. The CHABA differentiated its proposed limits based on the decay rate of the impulse energy. Impulses that oscillate after the initial impulse have more energy, and thus can cause more damage, so CHABA proposed slightly lower limits for these types of impulses. The Levels Document used this slightly more conservative estimate for the limits it proposed for impulse noise.

The Levels Document also discussed how the number of impulses experienced per day affects hearing loss from impulse noise. This discussion briefly summarized a number of studies that proposed different curves for adjusting the allowable peak pressure in an impulse based on the number of impulses per

day. The Levels Document stated that an equal energy curve centered on 100 impulses per day approximately fit the data presented in these studies. Using the equal energy curve, the Levels Document suggested an adjustment of the limit given by the dashed curve in Figure 19 by -10 dB for every 10-fold increase in the number of impulses per day above 100. For example, a 1 ms impulse gives a nominal limit of about 140 dB for 100 impulses per day. For 1000 impulses per day, the acceptable level is 130 dB. For 10 impulses per day, the acceptable level is 150 dB.

The Levels Document provided other adjustments for factors like the rate of repetition of the impulses and an adjustment for the angle of incidence on human ears. Overall, the authors provided an absolute limit of 167 dB peak SPL for impulses having durations less than 25 microseconds, regardless of the number of impulses per day. The plot in Figure 19 summarizes the limits proposed by the Levels Document for different durations and frequencies of impulses.

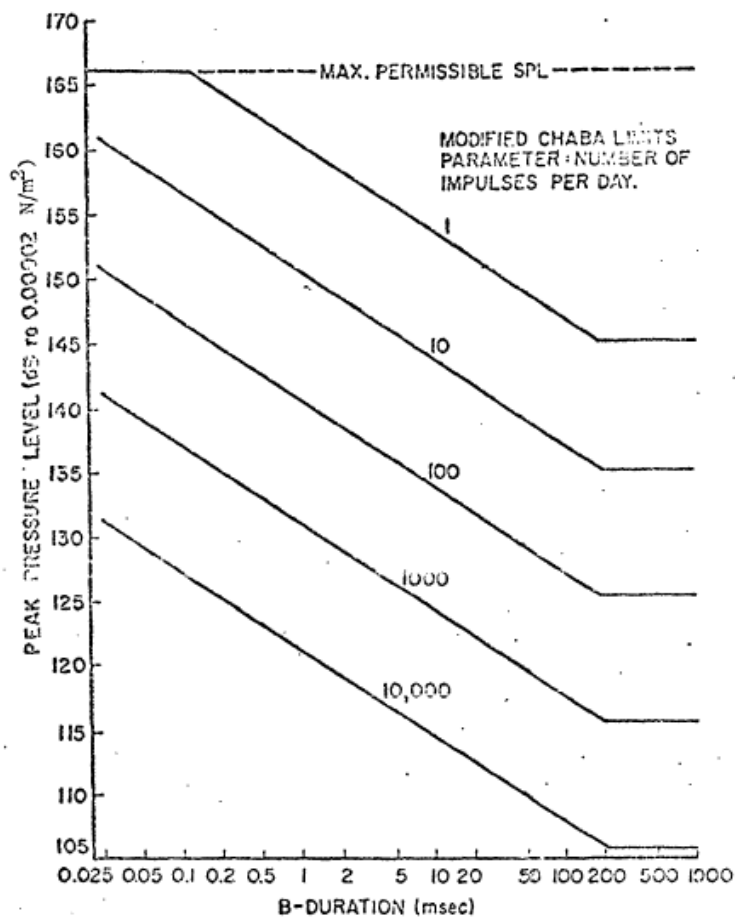


Figure 19. Impulse noise limits to protect against hearing loss as a function of duration of the impulse, based on the CHABA 1968 limit curves. The different lines represent limits for different numbers of impulses experienced per day. The actual limit is a function of the duration of the impulse. The longer the impulse, the more energy the impulse contains, and thus the noise level limit must be lower to prevent the same amount of damage to the ear.

The Levels Document specified that there was limited information to inform the choice of a level requisite to protect against annoyance or sleep disturbance from impulse noise, and that there was no clear evidence of permanent effect on public health and welfare at the time of study.

This section of the Levels Document also discussed sonic boom noise and the available information at the time of writing. The discussion was mostly based on data collected from an Oklahoma City study of 1964 where residents were regularly exposed to sonic booms for six months. The study used annoyance and interference surveys to assess the relationship between peak overpressure of the boom and these effects. The resulting recommendations were to limit peak overpressure based on the number of booms per day.

HUD's noise regulation 24 CFR §51.103(b) defines an interim standard when loud impulsive sounds are experienced at a site. The "day-night average sound level produced by the loud impulsive sounds alone shall have 8 decibels added to it in assessing the acceptability of the site... Alternatively, the C-weighted day-night average sound level ($L_{c,dn}$) may be used without the 8 decibel addition, as indicated in §51.106(a)(3)." Appendix I to Subpart B to Part 51 defines a loud impulsive sound as one for which:

- i. The sound is definable as a discrete event wherein the sound level increases to a maximum and then decreases in a total time interval of approximately one second or less to the ambient background level that exists without the sound; and
- ii. The maximum sound level (obtained with slow averaging time and A-weighting of a Type 1 sound level meter whose characteristics comply with ANSI S1.4-1971) exceeds the sound level prior to the onset of the event by at least 6 decibels; and
- iii. The maximum sound level obtained with fast averaging time of a sound level meter exceeds the maximum value obtained with slow averaging time by at least 4 decibels."

3.1.2 Current State of Research on Impulse Noise

3.1.2.1 *Hearing Loss from Individual and Repeated Exposure to Impulse Noise*

The CHABA report referenced in the Levels Document continues to be one of the better measures of damage risk from impulse noise exposure available today. This report is still referenced today in many studies and standards. To protect 95% of the population from 20 dB NIPTS, CHABA proposed the curves shown in Figure 20. The A-duration curve limits impulses with rapid, non-oscillatory decay rates. The B-duration curve limits impulses with oscillatory decay patterns.

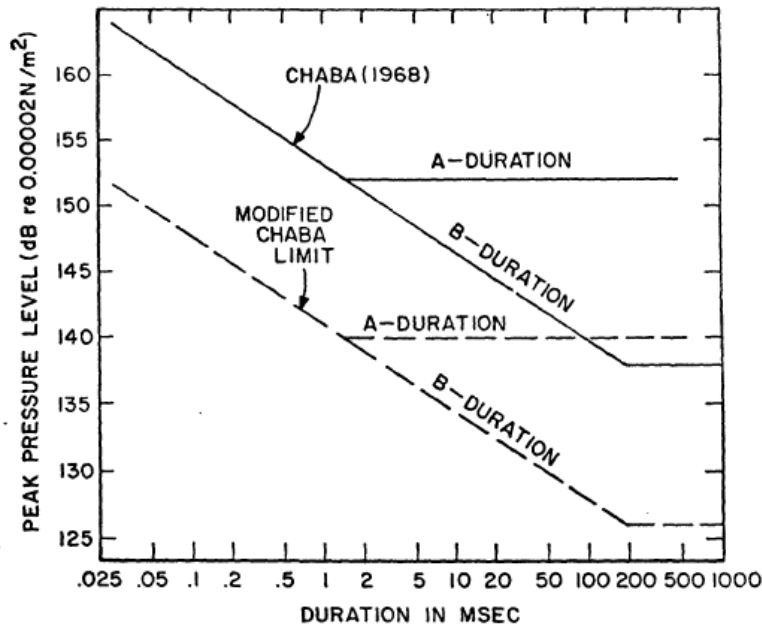


Figure 20. CHABA Impulse Noise Limit Curve, with the Levels Document Adjustment to protect 90% of the population from 5 dB NIPTS.

While the CHABA report is still applicable, the U.S. Army Research Laboratory has sponsored the development and validation of a model that uses fundamental concepts of physics and biology to analyze the human hearing system. The Auditory Hazard Assessment Algorithm for Humans (AHAHAH) was developed in the 1980s and continues to be validated by peer reviewers and researchers. The U.S. Army uses the model to predict hearing loss from gunshots, and the American National Standards Institute has shown interest in creating a standard for this model (Price 2010).

Other than the development of AHAHAH, there have been a number of studies on occupational noise exposure and hearing loss, many of which note that the study subjects were exposed to some type or level of impulse noise in these occupational settings. Because these are cross-sectional studies on very specific populations, the noise exposure situations are often unique and there is little consensus in the levels of impulse noise exposure required to produce specific levels of hearing loss. Many studies note the presence of impulse noise in the noise environment under examination, but do not measure the duration, number experienced per day, repetition rate, or even the peak sound pressure level of the impulses. These studies focus on the overall noise exposure, often over the course of an 8-hour workday. Therefore, these more recent studies do not offer a greater understanding of hearing loss effect of impulse noise than the CHABA report from the 1960s (Lie, Skogstad, et al., 2015).

Despite the variability and lack of specificity of data on the effect of impulse noise, researchers generally agree that impulse noise can be more damaging to the human hearing system than the amount of sound energy in an impulse would predict using a model of hearing loss based on continuous noise. Because of this, many standards and regulations recommend a 5 to 10 dB reduction in the applicable continuous

noise limit if impulse noise is present in the noise environment (Lie, Skogstad, et al., 2015; Starck, Toppila, Pyyko, 2008).

HUD's regulation and interim standard for impulse noise aligns with the 5 to 10 dB range in noise level penalty recommended by some standards and regulations. This interim standard approximates the increased risk of physiological damage of impulse noise by raising the post-development ambient noise level by 8 dB. As a programmatic response, it is simple, easily communicated, and effectively reduces the assessment burden on grantees while protecting public health and investment. However, this adjustment is in contrast to the Level's document recommendation to assess continuous noise and impulse noise separately. Additionally, substantial research has not yet been performed that allows for the assessment of the individual hearing loss effects of impulse noise separate from continuous noise. Therefore, the validity of a penalty on ambient noise levels or a reduction in applicable noise level limits cannot be verified until more specific and focused data are available which updates the information and relationships in the original CHABA report.

3.1.2.2 Annoyance to Non-Aircraft Impulse Noise

Although the levels of impulse noise that cause hearing loss are well understood, the effects of such as annoyance from longer-term exposure to lower energy impulse noise is not as well understood. There is very little research on environmental impulse noise besides sonic boom impulse noise, making it difficult to perform community annoyance surveys addressing impulse noise (Fidell and Pearsons 1994). The few survey-based studies on annoyance from environmental impulse noise were mostly carried out in Europe as early as the 1970s, with the most recent studies being carried out in the early 2000s. While some of these studies recommend the use of certain metrics in exposure-response correlations for impulse noise, they often specify many caveats and admit that the data differ significantly from other studies (Rylander and Lundquist 1996; and Brink and Wunderli, 2010).

Across most discussions and research papers reviewed, it is generally agreed that annoyance from impulse noise is greater than continuous noise. One researcher suggested that annoyance from impulse noise grows at twice the rate as annoyance from non-impulse noise events of numerically equivalent A-weighted SEL (Fidell, Pearsons, Feb. 1994). Some studies show that C-weighted metrics correlate better with annoyance from impulse noise than typical A-weighted metrics. C-weighting better accounts for lower frequency noise present in impulse noise. (Page, 2014; Maglieri, 2014; and Fidell and Pearsons, Feb. 1994).

Studies sometimes report annoyance to impulse noise in relation to the level of continuous noise that causes the same amount of annoyance in the study population. In these cases, the difference between the cumulative impulse noise level and continuous noise level to cause the same amount of annoyance ranges from 5 to 12 dB across studies. The range in the differences reported indicates more standardized study tactics need to be employed to obtain a more focused difference in sound level. Additionally, while these reported metrics might capture a study population's reaction to cumulative impulse noise exposure, they do not take into account other aspects of impulse noise that might cause annoyance. These other aspects include distribution of impulse events, rate of repetition, and wide frequency ranges, as discussed in the Levels Document (Fidell and Pearsons, Feb. 1994; Fields, 1997; and Maglieri, 2014).

3.1.2.3 Annoyance from Supersonic Aircraft (Sonic Boom Impulse Noise)

Much of the available research data on impulse noise is focused on sonic boom noise exposure. There is a wealth of published laboratory based simulated sonic boom annoyance data. Laboratory studies can control the shape and amplitude of the sonic boom signature and the measurements of exposure levels have high confidence. Results from these early studies have pinpointed overpressure and rise time as the aspects of sonic booms that are most related to annoyance and perceived loudness (Maglieri, 2014). However, it is not straightforward to determine the relationship between laboratory studies on immediate annoyance from a singular sonic boom and community annoyance. Moreover, some syntheses admit that laboratory studies, while valuable, do not produce the type of data necessary for selection of a final metric and level to assess acceptability of exposure to such environmental noises (Fidell, Pearsons, Oct. 1994).

There have been several large-scale community exposure survey studies on sonic booms over time, mostly from 1965 to 1985.¹⁴ A more recent study was the Waveforms and Sonic Boom Perception and Response (WSPR) study at Edwards Air Force Base in 2011 (Page, 2014). These studies usually attempt to obtain exposure-response relationships by measuring sonic booms in a specific region and then distributing surveys in various forms to the exposed population. Generally, studies find that as the maximum air pressure during the sonic boom rises, so do levels of annoyance and reported complaints. Studies report similar trends for increases in the number of booms experienced per day.

Most published studies of annoyance to sonic booms use military-style aircraft to produce sonic booms. This is because commercial supersonic flight annoyance studies are difficult due to the ban on overland commercial supersonic flight operations. Military-style aircraft performing super-sonic dive maneuvers can simulate fairly well a boom signature that might be produced from a future supersonic commercial aircraft, but these studies can only be performed on localized and select populations (Fidell, Pearsons, Oct. 1994). One recent lengthy and in-depth synthesis report by NASA concluded that “selection of a final metric and level cannot happen until a demonstration vehicle having a low-amplitude shaped signature is flown to assess its community acceptance” (Maglieri, 2014, pp. 366).

Different assumptions and study procedures across the body of research make it difficult to compare the outcomes and establish recommended levels or metrics for annoyance to sonic boom. Annoyance survey design, assumptions about prior exposure to impulse noise, and different exposure timelines all factor into differing study outcomes. Fields specified, “... it is not possible to predict the size of [the difference in reaction between continuous noise exposure and sonic boom exposure]” (Fields, 1997, pp. 65). Page et al. presents a plot comparing WSPR data points with other sonic boom and impulse noise annoyance data. The distribution of these data points does not indicate any immediate trend between sonic boom or other impulse long-term noise exposure and percent of the study population that was highly annoyed (Page, 2014, pp. 158).

¹⁴ Studies frequently referenced include the 1965 Oklahoma City study mentioned in the Levels Document, a 1962 St. Louis study, a 1970 study by NASA conducted in Chicago, Denver, Atlanta and other cities (Maglieri, 2014), and a 1984 long-term exposure study in Nevada (Fields 1997).

While conclusions about metrics and levels are difficult to reach from currently available research, there has been renewed interest from multiple agencies in the U.S. Government, as well as international entities, to explore the reintroduction of supersonic flight in the commercial aviation market. NASA's "Quiet Super Sonic Flights 2018" project was carried out near Galveston, Texas as a baseline to understand noise levels and community annoyance in preparation for tests with an experimental low-boom supersonic vehicle. The term "sonic thump" is being used to describe these shaped, lower peak overpressure booms. The hope is that with lower, shaped sonic booms, annoyance will decrease in the exposed population.

3.1.3 Summary and Research Gaps

The hearing loss effects of impulse noise were relatively well understood at the time of the writing of the Levels Document. The Levels Document put an absolute limit of 167 dB on impulses below 25 microseconds in duration, with varying lower limits on longer impulses dependent on the number of impulses experienced per day. As an overall limit applying to standalone impulses of any duration, the Levels Document provided a limit of 140 dB.

There has been some development of new models to assess hearing loss, but earlier CHABA research remains relevant and applicable today. Some newer studies attempt to measure permanent hearing loss as a result of exposure to noise environments which include impulse noises, but there is little consensus among the research, and they often do not report specific information about the impulses themselves. One conclusion that research generally has agreed on both at the time of writing the Levels Document and presently is that it is more accurate to assess the hearing loss effects of impulse noise separately from continuous noise. Assessing these effects in studies requires controlling for a large number of variables, including exposure to continuous noise, which can be difficult to do in cross-sectional studies. Currently, there is not sufficient research that accomplishes these types of controls, but longitudinal studies on the individual effect of impulse noise on hearing loss that control for extraneous variables may lead to more consensus in the research community. Additionally, in modern hearing loss studies, noting actual acoustical characteristics of impulses when assessing environmental or occupational noise, rather than only noting the presence of such sounds in the noise environment, will help validate or invalidate the current interim HUD standard.

Specific annoyance studies on non-aircraft impulse noise are limited and usually focus on cumulative noise exposure metrics, as well as peak sound level during the event. To improve the understanding of impulse noise annoyance, future research should consider aspects of impulse noise that might cause annoyance other than cumulative exposure or peak sound level. Future studies should seek to align specific study parameters, procedures, and assumptions for comparison, as these factors can substantially change the outcomes of a study. This alignment may lead to the development of a more widely applicable exposure-response relationship for annoyance to impulsive noise.

There is renewed interest in research on annoyance from sonic booms, exemplified by recent and currently ongoing NASA studies. NASA's "Quiet Super Sonic Flights 2018" and related upcoming research aims to study reactions of non-acclimated residents to shaped, low-amplitude sonic booms from an experimental aircraft. This will directly address the gaps in data on shaped-boom demonstration vehicles reported by Maglieri in 2014. In addition to low amplitude boom research, other gaps include the lack of

focused procedures for studying differences in annoyance from single events and cumulative exposure, as well as the number of booms experienced per day (Page, 2014). These procedures will produce data sets that are more comprehensive and in turn more confident correlations and metric recommendations.

3.2 Stationary Noise Sources

While the majority of this report focuses on the adverse effects from transportation noise sources, there are a variety of other, “stationary” sound sources that can cause substantial environmental noise. Stationary sources can elicit similar reports of annoyance, sleep disturbance, and activity interference from residents as do transportation sources. Most transportation noises are intermittent, with individual transportation events occurring at relatively regular intervals. Conversely, stationary noise sources are often continuous during times when the facility is operational. Various individual noise sources and activities, with different noise and operational characteristics, emit different sounds throughout the working period. Because of the differences from transportation noise sources, the sounds from stationary sources must be treated differently in measurement procedures and when considering the relevant adverse effects (Murphy, King, 2014).

This section describes the noise characteristics of quarries, rail yards, industrial sites and temporary construction, wind turbines, and commercial space launch sites.

3.2.1 How the Levels Document Addresses Stationary Noise Sources

The authors of the Levels Document did not address stationary noise sources directly. Certain stationary sources were mentioned throughout the discussion in the appendices, but specifics and in-depth discussion about the noise levels and other information about those sources was not included. One area where stationary sources were mentioned was in the recommended levels of environmental noise given in the final section of the narrative of the document. Noise levels to protect against hearing loss and activity interference were presented for a number of different land use categories. Among these categories was industrial land uses. It was noted that the variety of activities carried out in industrial areas may make it difficult to determine a level to protect against activity interference, so only the level to protect against hearing loss, 70 dB L_{Aeq} for 24 hours of exposure, was provided.

The Levels Document provided some discussion in the appendices that indicated while industrial and construction noises were not widespread relative to other noise sources, when industrial operations were nearby, they generated substantial complaints, and even the threat of legal action. The glossary also mentioned industrial sites in the definition of Impulse Noise, noting that these types of noise may characteristically be associated with explosions, impacts, discharge of firearms, and many industrial processes. Some specific stationary sources were also identified in the Impulse Noise section of this document. For example, metal-to-metal impacts in industrial processes were identified as having a peak noise level of 120-140 dB in close proximity to the sound source.

3.2.2 Discussion of Specific Stationary Sources

The following sections include general discussions of a few notable stationary noise sources. Specific data are provided where available. The qualities of the noise produced in these sources have many

similarities between them, including potential for impact noises, pure tone frequencies, and intermittent variable sounds, as well as the variety of locations these sources can exist.

3.2.2.1 Quarries

Quarries are a type of open-pit mine usually used to extract different types of stone from the ground to be used as building materials. Unlike sub-surface mines that consist of tunnels and shafts, quarries are open to the surface of the earth. They are usually an inverted conical pit in the ground, expanding downward and outward as material is either dug or blasted from the sides of the pit. Quarry locations can vary greatly, but active quarries are rarely located in densely populated urban areas. Usually, the closest residences are located several miles away from the actual quarry; however, sometimes homes are much closer and quarry access roads sometimes pass very close to residential properties. Thus, the noise from heavy trucks traveling on these roads must also be accounted for when assessing the environmental noise impacts of the quarry (Thomas, Liu, 2013). These traffic noise sources will not be discussed in depth in this section, as these are not characterized as stationary sources.

Methods of extracting material from the quarry include blasting, drilling, and operating diesel-powered excavation tractors and other equipment. Other noise-making activities at quarries involve jaw crushing of stone material, moving and processing material with conveyer belts or large trucks, loading trucks or rail cars for transportation away from the quarry site, and operation of those vehicles within the site boundaries.

Quarry noise sources can have different qualities and produce different noise levels for different amounts of time. Explosions from blasting produce impulse noises that might be up to 120 dB for durations under 1 second. More sustained noise is generated from operation of vehicles or equipment with internal combustion engines or from on-site processing of the extracted material. Motorized machines can range from excavating equipment to dump trucks, all of which are used in different areas of the mine and thus can result in different noise levels at receiver locations. Most equipment used in quarries ranges between 80 and 100 dBA L_{max} when measured from 50 feet away. When the distance to receivers, shielding, and ground and air absorption are taken into account, models usually show that noise from quarry operations ranges from 35 to 53 dB L_{den} , with receivers ranging from 2,000 ft. to around 6 miles away from the noise sources within the quarry property (Benchmark Resources, 2011; Bansah, 2015; Thomas, Liu, 2013)

One interesting aspect of quarries is that, as excavation activities dig deeper into the earth and the mine reaches greater depths, there is more shielding from residential receiving locations. Thus, many studies and models report that the noise level will decrease over an extended period as the quarry is dug deeper. While this shielding may result in some attenuation, additional reflections of sound waves from the sides of the quarry would reduce the amount of attenuation actually experienced at receiver locations. Sophisticated computer modeling may be necessary to accurately predict future noise at mid-to end-state quarry development. HUD's regulation requires noise projections 10 years from project occupancy (24 CFR 51.106(e)).

The qualities of the sounds produced from quarries and experienced at residential receiver locations vary in frequency content, duration, and overall contribution to an average daily noise level. As noted

previously, blasting operations may produce very loud, very brief sounds. While the durations of blasting noises are short, depending on how often and the time of day at which they occur, they can elicit annoyance responses anytime and sleep disturbance if they happen early in the morning. Steady state sounds produced by heavy machinery engines and material processing produce lower levels of noise overall but the sustained nature of these sounds increases the effect they have on humans listening to the sound. Pure tone content in these sounds might also increase the annoyance effects these sounds might cause.

Regulations usually applicable to quarry noise is specific to the state or region in which the quarry is located. Some regions include noise limit standards in zoning regulations. Mendocino County in California, for example, provides limits specifically related to surface mining depending on the length of time the sound occurs. The maximum sound allowable is 85 dB in any moment (i.e., L_{max}) and down to 65 dB for 30 minutes (i.e., L_{Aeq}). Other regions utilize general standards for findings of significant impact based on increases to ambient noise levels from other sources caused by the project, in this case development or expansion of a quarry. In these cases, if the project is predicted to increase the ambient noise levels in the area by a certain amount, certain abatement measures are required (Benchmark Resources, 2011; Mendocino County, 2017).

3.2.2.2 Rail Yards

Rail yards are large properties containing many parallel sections of rail that are used to organize and build trains from individual rail cars. Rail is an efficient way to move freight over long distances, so rail yards are usually the interface between freight trucks and freight rail. While some rail yards can be located in rural areas and far from receivers, they are often located in densely populated urban areas with many residential receptors in close proximity. Due to the size of these facilities, many residences can border a single rail yard, and the noise can be hard to mitigate with barriers. A common aspect of rail yards is the long hours of operation. The 24-hour nature of the freight rail industry necessitates operation throughout the day and night, which increases the risk of sleep disturbance for residents surrounding these sites.

The range of noise levels experienced by residential noise receptors around a rail yard varies with the size of the yard, the types of rail industry the yard serves, the design of the yard, and the frequency and duration of activities occurring in those areas. The FTA Transit Noise Vibration and Impact Assessment Manual includes a reference level of 118 dBA Maximum SEL as the typical maximum sound level experienced 50 feet from the center of a rail yard. Individual noises emanating from the rail yard may vary significantly from this reference level. The FRA sponsored a measurement campaign in the 1980s with the goal of assessing occupational noise sources on rail yards. This research report gives a good idea of ranges of noise levels produced by specific activities on a rail yard. Table 13 shows some values for noise levels reported in the FRA study from different rail yard activities. An approximation of the sound level at 50 feet away is also shown in parentheses. For the most part, the maximum values shown here are in good agreement with the maximum SEL given in the impact assessment manual.

Table 13. Selected noise levels and qualities of noise producing activities in rail yards measured 100 ft. away from noise source. Values in parentheses indicate an approximate sound level adjusted to 50 ft. from the sound source (Urman, 1987).

Noise Source	Noise Level (L _{Aeq} for duration of activity)	Qualities
Moving Locomotive	76-80 (82-86) dB	Steady state, broadband noise with elevated low frequency content.
Idling Locomotive	65-71 (71-77) dB	Steady state, broadband noise with elevated low frequency content.
Car Coupling Impacts	91 (97) dB	Short duration impact noises, sometimes with pure tone content.
Car Retarders	110 (116) dB	Very high-pitched squeal, with pure tone content ranging from 2 to 4 kHz.

One major concern many residents voice is the noise from rail yard retarders. These retarders are essentially brakes attached to short sections of track that slow the movement of free rolling freight cars as they move from one end of the rail yard to another. Retarders work by clamping down on the rolling wheels of a car as it moves through the section equipped with a retarder. The friction between the retarder and the moving wheel causes the wheel to vibrate and emit a high-pitched, sustained noise that can reach the levels shown in the table above. These noises are intermittent but can occur at frequent and varying intervals depending on the switching activities in the yard. As retarders are located in many places throughout a railyard, including near the property boundary, it is easy for residential receivers to be located quite close to these sound sources. Retarder noise can cause activity interference, annoyance, and possibly cardiovascular effects due to the high pitched, pure tone frequencies that are included. One notable example from Bellevue, Ohio had residents surrounding a rail yard issue a lawsuit against the freight company that owned the yard regarding the retarder noise. Residences reported that the sustained noises resulted in speech interference, other activity interference, sleep interference, and decreases in property value (Ouriel, 2017).

Federal regulations¹⁵ enforced by FRA limit the sound from all rail sources including rail yards. In addition, NEPA guidance¹⁶ requires analysis of predicted impacts for proposed projects and consideration of abatement measures. Impacts are separated into no impact, moderate impact, and severe impact categories depending on the predicted noise level as a result of a project's implementation, and the existing noise level in that area. Federal requirements to limit noise at rail yards are summarized in Table 14. State or public policies that relate to general environmental noise levels may also apply depending on the location of the rail yard.

¹⁵ 40 CFR Part 201 (EPA) and 49 CFR Part 210 (FRA)

¹⁶ FTA Transit Noise Vibration and Impact Assessment Manual, which also applies to FRA projects

Table 14. FTA and FRA noise standards for rail yards

Stationary Rail Noise Source	Noise Standard at the Receiving Property	Reference
Retarders	83 Ladjavemax(fast)	40 CFR Part 201.14
Car-Coupling Operations	92 Ladjavemax(fast)	40 CFR Part 201.15
Locomotive Load Cell Test Stands	65 dBA L ₉₀ (fast)	40 CFR Part 201.16
All rail sources, new projects	L _{dn} at residential land uses. Level depends on existing and project noise exposure	FTA Transit Noise Vibration and Impact Assessment Manual

Ladjavemax = Adjusted average maximum sound level

L₉₀ must be validated by determining that L₁₀-L₉₉ is less than or equal to 4dB (A)

3.2.2.3 Industrial Sites and Temporary Construction Sites

3.2.2.3.1 Industrial Sites

Similar to rail yards, industrial sites can be located anywhere ranging from sparsely to densely populated areas. Factories, freight distribution centers, ports, workshops, refrigeration plants, and power generation plants are all basic examples of industrial sites that can produce substantial amounts of noise. When these sites are located in urban areas, the number of residents that may live near them can be substantial. The noise from these sources can affect residential areas in different ways and at different levels.

It is difficult to characterize noise from industrial activities because there are many different pieces of machinery or activities that make noise. The combined effects from individual sources are often difficult to model due to varying noise characteristics, types of sites, and surrounding areas. However, the European Commission Working Group Assessment of Exposure to Noise developed some basic default values for different types of industrial areas. These levels are given in terms of sound power in dB per meter squared (L_{WA}/m²). The levels have been converted here for ease of comparison to sound pressure level at 100 ft. from the sound source. Table 15 shows these sound levels. The exact definitions of these land use types is not specified. The source database for the levels in the table gives other defaults for specific industrial use types. A selection of these are also included in the table (European Commission WG-AEN, 2007; van den Berg, 1999).

Table 15. Sound Pressure Levels from Industrial Land Uses from the European Commission Working Group

Type of Industrial Use	Sound Pressure Level at 100 ft. (30 m) (dB L _{Aeq})
Heavy Industries	57
Light industries	52
Commercial Uses	52
Ports	57
Refineries	62
Gravel/Ore/Coal Transfer Stations	57
Warehousing Facilities	47
Outdoor Shipyard	62

While the values listed above are time-based average sound levels, the noise emanating from an industrial area can vary significantly throughout the day, the week, or even seasonally. Manufacturing processes can produce impact or impulse noises, pure tone frequencies in high and low frequency ranges, and intermittent noises at varying frequencies depending on the activity. Developers often must model sound from each of these activities to produce an overall estimate of the community noise that will be produced from the project (Murphy, King, 2014).

A number of actions can be taken by industrial site managers or owners to reduce the noise created by their site. Noise attenuating exterior walls can be used to reduce the amount of noise that exits the facility. For reasonably small outdoor industrial sites like logging mills, noise barriers between residential land and the facility can be a feasible method of reducing the amount of noise that reaches the receiver. Industrial equipment often comes with noise ratings that specify the sound power produced when in operation. Purchasing equipment that has a lower noise emission rating can help reduce the overall noise levels produced while the facility is operational (Murphy, King, 2014).

There are few regulations that directly limit the noise produced by industrial sites. In the U.S., new industrial projects often must go through an environmental impact analysis process. Increases in ambient environmental noise in surrounding areas due to the project are categorized and project sponsors commit to different abatement actions based on the degree to which noise levels will be increased. These analyses require noise modeling procedures and measurements of existing ambient noise levels to determine the overall effect that changes to existing site or a new industrial site will cause.

3.2.2.3.2 Construction Noise

Temporary construction sites can often be located in very close proximity to residential areas, especially in cities where infrastructure projects constantly necessitate the use of loud machinery and activities close to apartment buildings or row houses. Demolition, diesel engine sounds, cutting building materials, and air or water pumps are all examples of high noise producing activities that might be found in a temporary construction site. In addition, the need for construction projects to adhere to timely schedules often requires long working days that begin early in the morning such as at 7 am.

British Standards have provided a database of standard noise levels produced by some construction activities. These standards are used for noise and vibration control on construction sites. Some examples of levels produced by certain activities is shown in Table 16. These levels are sustained L_{Aeq} values measured 30 feet (10 m) from the noise making activity.

Table 16. Noise levels from individual pieces of construction equipment used in British construction noise standards

Equipment/Activity	L_{Aeq} (dB(A))
Bulldozer Clearing Site	75
Water Pump	65
Hydraulic Hammer	89
Gas Powered Circular Saw	91
Angle Grinder	80

As with industrial noise sources, the continuous noise values shown above do not necessarily capture any tonal qualities or intermittency that might occur as construction work is carried out. Therefore, the overall L_{Aeq} or L_{dn} metrics may not be sufficient to characterize the noise effects that construction has on the surrounding area.

Similar to industrial noise sources, a number of precautions or actions can be taken to reduce noise from construction sites. Noise attenuating fencing around construction sites has been shown to have an effect on the noise levels emanating from a site. Particularly noisy activities can be scheduled during less noise sensitive times of the day, often when people are at work. As with industrial equipment, construction equipment is often rated for the noise it produces. Purchasing quieter equipment can reduce the overall noise level produced at a construction site.

Regulations that limit construction noise are usually most concerned with the time of day at which construction sites may operate. Usually, sites are only allowed to operate between 7 am and 7 pm, times that are focused on reducing sleep disturbance. These allowable times may vary from one regulatory region to another. Some regions have specific noise level restrictions depending on the activities being carried out and the time of day they are occurring (Berkeley, CA Construction Noise Standards; Murphy, King, 2014).

3.2.2.3.3 Adverse Impacts of Noise from Industrial and Temporary Construction Sites

Because of the variety of types of sounds produced from industrial sites and construction sites, a value of L_{dn} describing noise from an overall industrial source might not capture the specific types of sound that might be produced. Impact noises in factories, continuous whirring from refrigeration plants, and intermittent operation of bulldozers and tractors can all have different adverse effects on communities and residents in affected areas. Combinations of these types of sounds can result in simultaneous occurrences of adverse effects, which is describe in detail in the adverse effects section of this report.

Some studies have shown that residents in surrounding areas are less annoyed or bothered by noise from industrial and construction noises when they feel the site owner or operator has proven to be a “good neighbor.” In other words, they communicate well about the noise produced in their site, express mutual concern when neighbors object to activities being carried out, and show that actions are being taken to reduce the impact the site has on surrounding areas. A very rough estimate has shown that the level of communication can have a +5 dB allowance or a -5 dB penalty depending on the level of communication with surrounding residents (Murphy, King, 2014).

Despite the options of noise mitigation techniques available to industrial site operators, the most effective method of reducing industrial noise impacts on residents is to limit the number of residents that can live in the immediate vicinity of an industrial area. Land use planning around industrial land uses is an important part of mitigating effects of noise on humans, and preventing residential development near these sites should be a priority for operators and local governments.

3.2.2.4 Wind Turbines

Wind turbines are not often located in highly populated areas. While there has been an increase in the number of large wind farms installed in the U.S. and internationally, most are either in rural or forested areas relatively far away from highly populated regions. It is difficult to install a large wind farm facility

in a densely populated area due to the large amount of property needed. There are, however, examples of individual wind turbines located in urban areas that may be more of a concern for surrounding residents. Several states in the U.S. have published recommendations or statutes regarding minimum distances of wind turbines or wind farms to residential areas. Distances defined by the statutes usually depend on the power output and maximum blade height of the turbine. A few notable examples are shown in Table 17 (Heibel, Durkay, 2016).

Table 17. Selected state standard or statute regarding distance of wind turbines to residential locations.

State	Standard or Statute Setback Distances
Connecticut	Distance to any property lines: <ul style="list-style-type: none"> - Greater than 65 megawatts: Distance \geq 2.5 times height of turbine - Less than 65 megawatts: Distance \geq 1.5 times height of turbine
Kentucky	1,000 Feet from property boundary of residential land owner, and 2,000 feet from residential neighborhood, school, hospital or nursing home facility
Ohio	Between 5 and 50 megawatts: Distance \geq 1.1 times height of turbine, and 1,125 feet from property line
Wisconsin	Distance to residences: <ul style="list-style-type: none"> - Residences on property not hosting turbines: Distance \geq 3.5 times height of turbine - Residences on property hosting turbines: Distance \geq 1.1 times height of turbine

Wind turbines and wind farms usually produce a combination of aerodynamic and mechanical noises. The main source of aerodynamic noise from wind turbines is from vibration of turbine blades as they rotate. The force of the wind on the moving blades causes vibrations at low but possibly audible frequencies. Because of the circular movement of the blades, the sound level caused by these vibrations might rise and fall in a regular pattern, a concept called amplitude modulation. There is some evidence that amplitude modulated noise can be more annoying than other patterns of noise, but the perception of amplitude modulated noise is a complicated issue and more research is needed. Mechanical noises produced from wind farms include the movements of the generators, but the raised height of the generators means there is often significant attenuation of noise between the source and the receiver. Occasionally, maintenance equipment on the ground may produce noise at these sites, but noises from trucks driving and construction activities will be extremely brief and temporary (Murphy, King, 2014).

Another concern surrounding the noise produced by wind turbines is the possibility of emitting infrasound. The limitations of human hearing significantly reduce the perception of sound below 20 Hz. Even at very high sound pressure levels, infrasound is not likely to be audible. The implication is that annoyance and hearing loss are not usually considered as possible direct effects of exposure to environmental infrasound. However, concerns about neurological, cardiovascular, and genetic abnormalities due to infrasound exposure have been considered. These health effects have been summarized colloquially as “wind turbine syndrome,” as residents attribute those symptoms to this phenomenon.

Scientific studies have generally been unable to provide conclusive evidence showing whether the noise from wind turbines can have negative health effects on surrounding residents. A few scientific studies have indicated that some specific health effects may be associated with infrasound at extremely high sound energy levels. Despite this possibility, several Australian studies have shown that natural sources of infrasound and low frequency audible sounds are similar to those produced by wind turbines and in wind farms (Murphy, King, 2014).

The Basner and McGuire study discussed in the sleep disturbance section included a review of studies on wind turbine noise and sleep outcomes. Out of six studies reviewed, four of them found an association between wind turbine noise levels and increased sleep disturbance. These studies found that sleep disturbance due to wind turbine noise may occur when noise levels are above 40 or 45 dBA.¹⁷ However, for two of the studies less than 10 percent of study participants were exposed to these levels, making it difficult to draw conclusions to the broader population. The possible effects of infrasound at different levels should be researched further in order to build robust understanding.

The noise produced by wind turbines changes significantly with the speed of the wind. Higher wind speeds usually generate higher background noise levels, making it challenging to distinguish the effect of wind turbines on environmental noise. Therefore, analysis is usually performed on the wind turbine noise and the background noise levels at a variety of different wind speeds. As an example, a typical 3MW turbine produces overall sound power levels between 100 and 107 dBA at wind speeds ranging from about 10 to 20 mph. This translates to a range of between 42 and 49 dBA at a distance of 1,000 ft. Evidence suggests that, as wind speeds reach some critical value, the sound levels reach an asymptote and do not increase further. Other studies have calculated sustained sound levels of up to 44 dBA at high wind speeds (Murphy, King, 2014; ESS Group, INC, 2010)

Noise limits for wind turbines have been recommended by European working groups, and noise from new wind turbine projects are often regulated by existing local environmental standards that limit how much implementation of the project can increase the existing noise levels in the area. Often a limit of up to 5 dB above existing noise levels is recommended. Some regions allow 10 dB above ambient levels due to the project. This allows noise limits to increase slightly as both background noise and wind turbine noise increase with wind speed. Regulations usually require modeling of predicted effects on environmental noise in the surrounding areas before a project can be approved for development.

3.2.2.5 Commercial Space Launch Sites

Commercial space launches are becoming more frequent. Private companies are offering continuously cheaper options to send heavier payloads into orbit around Earth, supporting communications companies, scientific endeavors, and global navigation systems. Multiple companies are developing new rocket models for use in human space flight missions and missions with heavier payloads. Space launch sites are usually not located extremely close to any populated area, but because of the noise levels and frequencies associated with space launches, noise levels can be significant in areas miles away from the immediate launch site (Page et al, 2018).

¹⁷ The studies included in this review used different noise metrics; four used A-weighted sound pressure level (SPL), one used L_{den} , and one used L_{night} .

There are two important unique concerns for the noise produced by space launches. First, rocket engines produce very loud, very low frequency noise that can travel much further than sound waves at higher frequencies produced by other transportation sources. Lower frequency noise does not experience as much attenuation in the air as higher frequencies. This means that residents may hear rocket launches from miles away. Second, rockets usually reach supersonic speeds early on in their flight paths, so they produce a sonic boom in the areas over which they travel at these speeds. While many flight trajectories of space launches are above large bodies of water when the vehicles reach supersonic speeds, sonic boom impulses can travel far enough in air unimpeded such that they can reach residential areas on land. The development of reusable booster rockets should also be considered. These engines reenter the atmosphere at supersonic speeds and land at similar sites to where they took off. In these cases, multiple sonic booms are produced over the course of a rocket launch (Page et al, 2018).

To date, no measurement standards have been created or are widely followed to assess a space launch agency's impact on the surrounding noise environment. Because of the relatively recent acceleration in development and public attention on space flight operations, there are ongoing efforts to develop these standards. Some space launch companies have developed models predicting noise levels and sonic boom overpressures in areas surrounding the launch site. SpaceX, for example, predicted maximum noise levels of 100 dB $L_{A,max}$ at a distance 6 miles away from the launch site in Brownsville, Texas. A large section of the town of Port Isabel, including many residential areas, is included in this range. SpaceX also modeled noise from the landing procedures of its reusable rockets for a launch at Cape Vandenberg Air Force Base. Again, areas about 5 miles away from the launch point experienced noise levels up to 100 dB $L_{A,max}$ (Page et al, 2018).

Similar modeling exercises have been performed for the sonic boom overpressures experienced in areas surrounding launch sites. An important aspect of the sonic booms from rocket launches is that they are not heard near the actual launch point. Because rockets cover a substantial distance before reaching supersonic speeds, the sonic booms footprints are produced miles away from the launch site. For the same launch in Texas, SpaceX predicted the largest overpressures of 3 psf to occur 45 miles away from the launch site. In most cases, these footprints are distributed over the surface of the ocean; however if launches are ever performed over land, sonic booms would be a significant concern for residents in areas far away from the actual space launch site (Page et al, 2018).

Recently, the National Academies of Sciences, Engineering, and Medicine sponsored development of modeling methods for rocket noise and sonic booms during space launches in an effort to develop industry standards for these operations. This methodology includes in depth procedures to calculate environmental noise and sonic boom footprints during different stages of rocket flight. In addition, this project included development of a few modeling software systems that integrate the methods developed for ease of use and expedited modeling and analysis. In addition to modeling techniques, noise measurement procedures for different types of rocket launches are detailed. These include configuration of microphone arrays for overall noise level measurement as well as sonic boom measurements. Future work detailed in the report includes noise measurements of launch events, validations of the various models produced as part of this effort, and expansion of the spaceport,

spacecraft, and flight trajectory profiles to enhance the variety of scenarios that can be studied using the modeling software (Bradley, et al., 2018).

3.2.3 Summary and Research Gaps

Stationary sources of environmental noise vary significantly in size, sound quality, noise levels, locations, and in applicable standards and regulations. While developers are usually most concerned with transportation noise sources, stationary sources like industrial areas, quarries, and rail yards can all significantly contribute to noise levels in surrounding communities. Overall noise from stationary sources is usually a combination of noise from individual sources that can have varying noise levels during different times of the day and in different areas within the site. Fully understanding the effects of noise usually requires a comprehensive analysis of noise from that specific site. Overall, the most effective method for reducing impacts of noise in communities surrounding stationary noise sources is effective land use planning, including prevention of residential developments around these noise-producing sites.

There are some specific areas where more research would improve understanding of the adverse effects of these specific noise sources. Focused studies on the health effects of wind turbines should be performed to improve the general understanding of the impacts of environmental infrasound. Additionally, the perception of and possible annoyance from amplitude modulated noise from wind turbines should be studied. Noise from commercial space launches should be measured to assess community impacts, and methodologies to measure and model these launches should be further refined. New technology developments in both of these industries will warrant continued investigations of the related environmental noise impacts.

4 Gap Analysis and Recommendations

This section summarizes gaps and recommendations identified in earlier sections of this report.

Hearing Loss Research Gaps

The basic understanding of the noise levels that cause permanent degeneration of hearing ability has not changed substantially since the Levels Document was published.

Conduct longitudinal studies to improve understanding of the effects of cumulative noise exposure on human hearing. Although there are generally accepted standards for effects of continuous noise exposure on hearing levels, most of the studies used to develop these standards are cross sectional studies. Few sources of data have directly related noise exposure over time to hearing loss or threshold shifts. More longitudinal studies would improve the understanding of how cumulative noise exposure affects human hearing in the short and long term, how the hearing system recovers from temporary threshold shifts, and how excessive exposure contributes to hearing degeneration due to aging. Recent research on the biological processes (physiological, molecular, and mechanical components of the ear) that are affected by excessive noise may also contribute to understanding on the noise levels that affect hearing.

Activity Interference Research Gaps

For speech interference, there have not been substantial changes to the information presented in the Levels Document since it was published; therefore, no major research gaps were identified. For other activities (e.g., watching TV, relaxing, and other recreation), findings are based on asking about activities in surveys of annoyance, and one gap was identified.

Improve understanding of the relationship between activity interference and annoyance. It would be helpful to define the relationship between activity interference and annoyance, as interference with certain activities may cause more annoyance than other activities. A recommendation to build this understanding is to include questions in annoyance surveys about disruption of specific activities.

Annoyance Research Gaps

Overall, the authors of the Levels Document did not feel there was substantial evidence available to determine a level requisite to protect against annoyance beyond that associated with speech interference. Some aspects of an annoyance response to noise can be measured and observed objectively and quantitatively, while others are complex social and attitudinal differences between participants and regions that are often subjective and self-reported. While there has been substantial research on annoyance internationally, gaps in research on annoyance to noise are described below.

Account for confounding factors in quantifying percent highly annoyed. Despite the wealth of annoyance survey data available, there are large discrepancies in correlations derived from different data sets. Percent highly annoyed can range from 10% to 70% in different studies at the same noise exposure level. Research gaps to control for or quantify the effect of confounding, non-acoustic factors in annoyance studies include:

- Studying distributions of confounding variables both within study populations and across multiple studies to provide a better understanding of their overall effect.
- Developing systematic corrections for non-acoustical factors in order to reduce variance in the study data. This may include more focused survey questions or annoyance rating scales.
- Performing similar studies in the same region over longer periods. Differences in culture and general environment can be controlled for in this way.

Assess metrics used to describe annoyance. While L_{dn} is useful for describing long-term annoyance from cumulative noise exposure, it fails to capture qualities of the sound that may play a significant part in the annoyance exposure-response relationship. Alternate or supplemental metrics may be considered to describe the noise source in a way that captures these qualities. Models relating percent highly annoyed to other metrics may produce better correlations or have less unexplained variance and may be more representative of the exposure-response model described in this report.

Conduct noise annoyance studies in the U.S. Few annoyance surveys have been performed in the U.S. since the 1980s. The most recent published syntheses and research have been done exclusively on foreign study populations, and the results are difficult to extrapolate to the U.S. This gap is currently being addressed by the Federal Aviation Administration in a nationwide mail and telephone survey.

While the results of this survey are not yet published, the results are expected to update the exposure-response curves informing the FAA's consideration of national policy on aviation noise.

Health and Sleep Impacts Research Gaps

The Levels Document assumed that protection against noise-induced hearing loss is sufficient for protection against other health effects of noise. It is now well understood that noise levels lower than those necessary to cause hearing loss can lead to other negative health outcomes including disrupted sleep and adverse cardiovascular outcomes.

Understand and use new types of large-scale data collection to assess sleep impacts. As devices that use actigraphy to measure sleep based on wrist movements are becoming more widely available on the consumer market, there is an opportunity to use the data generated by these devices to study the connections between sleep and noise and to complement other methodologies such as polysomnography and questionnaires. An advantage of actigraphy is that it allows for data collection from larger numbers of people than polysomnography. Future work will be needed to manage and analyze this crowd-sourced data and to determine if the relationships between noise and sleep derived from actigraphy are similar to those from other forms of sleep measurement.

Assess metrics used to describe sleep disturbance. While most research studies of sleep disturbance or nighttime noise use cumulative metrics such as L_{dn} or L_{night} , further research is needed to determine whether the cumulative impact of noise or the effects of single noise events predominate in characterizing sleep disturbance.

Assess metrics used to describe cardiovascular impacts. Most studies of cardiovascular outcomes use L_{dn} , L_{Aeq} , or similar metrics that average noise across the day and/or night. However, further research is needed to determine whether these metrics, or metrics that focus on the effects of intermittent noise sources, should be used to predict cardiovascular outcomes.

Substantiate the relationship between noise exposure and cardiovascular and metabolic health outcomes. Although individual studies have shown a statistically significant association between noise exposure and adverse cardiovascular outcomes, there is not consistent evidence across studies for all noise sources and cardiovascular outcomes. The evidence for the effect of noise on metabolic outcomes is even more limited. Further research is needed to more definitively establish the relationship between noise exposure and cardiovascular and metabolic outcomes, and the noise levels at which these outcomes are experienced.

Assess demographics in the association between noise and health. The effects of noise on health may not be evenly distributed across a population. Age, other health conditions, or socioeconomic status may all affect how an individual responds to a given noise exposure. Further research is needed to determine how the association between noise exposure and health changes across different subgroups.

Determine the relative impacts of different interventions. Further research is needed to determine the relative impacts of different interventions on sleep disturbance and health outcomes, across all noise sources. If this research concludes that certain interventions have a greater health benefit for the same amount of noise reduction, these interventions should be encouraged.

Cognitive Effects Research Gaps

Noise disrupts children's learning not only by interfering with speech, but also by affecting memory and attention.

Consider studying how road, rail, and other noise sources affect cognition in home and school environments. Most studies consider the effects of aircraft noise, with few studies based on other noise sources. There is an association between exposure to aircraft noise and impaired cognition in children. Due to similarities in noise exposure between home and school environments, it is difficult to understand the underlying causes of the association between noise and cognition, such as sleep disturbance, speech interference, or distraction. Studying a variety of noise sources (i.e., aviation, road, rail, and stationary) and receptors (i.e. school and home) will improve understanding of the effect of noise on cognition.

Financial Impacts Research Gaps

While there is agreement in the research reviewed that an increase in noise is associated with a decrease in property values, there is not conclusive information about the magnitude of this effect.

Account for differences in study factors to understand how much noise affects property values. Even when studies use similar methodologies (e.g., hedonic regression), they study different geographic areas, housing types, and noise sources and control for different factors in the regression equation. A detailed analysis that accounts for differences in these factors, or conducting repeatable studies with consistent study parameters could help to determine the magnitude to which noise affects housing prices.

Consider applying the natural experiment methodology to validate hedonic regression. As researchers find opportunities to study financial impacts of noise before and after a change in noise exposure (e.g., conducting a natural experiment by evaluating a change in noise following a change in flight patterns or the installation of a noise wall). Potential sources of data are environmental assessments or environmental impact statements for projects that are expected to change noise levels in a community. Compare the results to results from a hedonic regression methodology to see if they are similar. This type of comparison may help to advance the state of knowledge about the most appropriate methodology for studying the financial impacts of noise.

Impulse Noise Research Gaps

The hearing loss effects of impulse noise were well understood when the Levels Document was published. The lack of modern research on the hearing loss effects of impulse noise separate from continuous noise is a gap to being able to validate standards that combine impulse and continuous noise. Specific studies on annoyance to non-aircraft impulse noise are limited. There is renewed interest in research on aircraft annoyance from sonic booms.

Measure acoustical characteristics of impulse noises when present in noise environments during hearing loss studies. Many studies on occupational or environmental noise exposure and the relationship with permanent hearing loss, only note the presence of impulse noise in the environment. These often do not measure the specific acoustic characteristics of the impulses, and focus only on

continuously measured noise levels. Measuring acoustic characteristics of impulses during these studies will provide more data from which to assess the individual effect of impulse noise on hearing loss.

Conduct more repeatable studies on annoyance to non-aircraft impulse noise in order to understand the exposure-response relationship. Available studies are limited, and the study design (parameters, procedures, and assumptions) differ too much for comparison across studies. Comparable results across more studies may lead to the development of a more widely applicable exposure-response relationship for annoyance to impulsive noise. One approach would be to create federal noise research guidelines that recommend funded researchers to include design elements, procedures, or questions that ensure comparability.

Continue to build knowledge on supersonic aircraft noise. Ongoing, long-term research includes developing experimental aircraft that create low-amplitude sonic booms and evaluating responses from populations who are not acclimated to sonic booms. Additional research gaps include developing standard procedures for studying differences in annoyance from single events, the number of events in a day, and cumulative exposure. These procedures will produce data sets that are more comprehensive, which will help in the selection of the best metrics to obtain the highest correlations.

[Stationary Noise Sources Research Gaps](#)

Stationary sources of environmental noise vary in size, sound quality, noise levels, locations, and in applicable standards and regulations.

Support effective land use planning techniques. Overall noise from stationary sources such as industrial areas, quarries, and rail yards is usually a combination of noise from individual sources that can have varying noise levels during different times of the day and in different areas within the site. Land use planning is the most effective method to reduce noise impacts on residents.

Build understanding on the possible effects of noise from wind turbines on humans. Possible effects may include health effects due to infrasound, perception and possible annoyance from amplitude-modulated noise, and sleep effects for residences in close proximity to wind turbines.

Continue to study and refine models and methods to assess noise and community impacts from commercial space launches. Development in technologies related to commercial space transport have garnered interest by industry. Launch sites with frequent use could produce concern by communities, and further investigation is warranted.

Annotated Bibliography

General.....	88
Hearing Loss.....	89
Activity Interference.....	90
Annoyance.....	92
Health and Sleep Impacts.....	95
Cognitive Effects.....	97
Financial Impacts.....	98
Impulse Noise.....	100
Stationary Sources.....	101

General

The following studies were cited in introductory sections of this report:

U.S. Environmental Protection Agency. 1974. *Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety*. 550/9-74-004.

<https://nepis.epa.gov/Exe/ZyPDF.cgi/2000L3LN.PDF?Dockey=2000L3LN.PDF>

Baseline for this research report. Developed in response to a requirement in the Noise Control of 1972.

U.S. Environmental Protection Agency. 1978. *Protective Noise Levels: Condensed Version of EPA Levels Document*. 550/9-79-100. <https://nepis.epa.gov/Exe/ZyPDF.cgi/20012HG5.PDF?Dockey=20012HG5.PDF>

This publication was intended to complement the Levels Document. It interpreted the contents of the Levels Document in less technical terms.

Federal Transit Administration. 2018. *Transit Noise and Vibration Impact Assessment Manual*. FTA Report No. 123. <https://www.transit.dot.gov/research-innovation/transit-noise-and-vibration-impact-assessment-manual-report-0123>

FTA guidance manual for noise and vibration. Includes: overview of noise; procedures for predicting and assessing noise and vibration impacts of proposed transit projects; descriptions of noise and vibration mitigation measures; construction noise and vibration; and how to present these analyses in FTA environmental documents.

Munzel, Thomas & Gori, Tommaso & Babisch, Wolfgang & Basner, Mathias. (2014). Cardiovascular Effects of Environmental Noise Exposure. *European heart journal*. 35. 10.1093/eurheartj/ehu030. https://www.researchgate.net/publication/260684620_Cardiovascular_Effects_of_Environmental_Noise_Exposure

Review by subject matter experts based on current literature on the mechanisms and impact of noise on the cardiovascular system. Describes the relationship among effects of noise on the auditory system, sleep disturbance, impairment of cognitive performance, stress, and health issues.

Hearing Loss

Sliwinska-Kowalska, M., Zabarowski, K. (2017). WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Permanent Hearing Loss and Tinnitus.

International Journal of Environmental Research and Public Health, 14(10), 1139.

<https://doi.org/10.3390/ijerph14101139>.

Systematic review of the possibility of contracting permanent hearing loss from extensive use of personal listening devices (headphones or earbuds) at loud volumes. The introductory section speaks briefly about hearing loss effects of environmental noise, but recognizes that no method of assessing the risks of hearing loss from environmental noise have yet been developed, and so the international occupational noise standard is used. The rest of the study focuses on hearing loss from PLDs. The study concludes that while there may be a higher risk of hearing loss in regular PLD users, better, more controlled studies would build understanding of the risk.

Johnson, D. L. (1973). Prediction of NIPTS Due to Continuous Noise Exposure. *Joint EPA/USAF Study, Aerospace Medical Research Laboratory, Wright Patterson Air Force Base, Ohio*. Report Number AMRL-TR-73-91/EPA-550/9-73-001-B.

Comparison of the relationship of noise exposure to noise induced permanent threshold shift as predicted by currently available works of Passchier-Vermeer, Robinson, and Baughn. The data from the three reports are presented in multiple tables, sometimes interpolated and sometimes extrapolated. A relationship between the degree of hearing loss and the amount of continuous noise exposure is derived from these data.

Johnson, D. L. (1978). Derivation of Presbycusis and Noise Induced Permanent Threshold Shift (NIPTS) to be used for the Basis of a Standard on the Effects of Noise on Hearing. *Technical Report, Aerospace Medical Research Laboratory, Wright Patterson Air Force Base, Ohio*. Report Number AMRL-TR-78-128.

Provides various sets of tables that attempt to summarize much of the existing knowledge of the expected effects of noise on the hearing threshold levels of a population. Relationships between noise exposure and NIPTS are derived for different frequencies and lengths of exposure.

International Standards Organization. (2013) ISO 1999:2013 (2013) Acoustics — Estimation of noise-induced hearing loss. <https://www.iso.org/obp/ui/#iso:std:iso:1999:ed-3:v1:en>

Internationally accepted and updated standard for estimating hearing loss due to occupational noise exposure. Can also be used to estimate hearing loss from environmental noise exposure. Presents procedures in statistical percentiles and at different exposure frequencies and levels.

Zechmann, E., Brown, R. (2015). ISO 1999:2013 User Written Matlab Package. *Package of Matlab functions, Matlab File Exchange*. <https://www.mathworks.com/matlabcentral/fileexchange/53565-iso-1999-2013>

Matlab functions written by Edward Zechmann and Richard Brown. The functions therein are implementations of the equations and algorithms presented in the ISO 1999:2013 standard.

Carroll, Y., Eichwald, J., Scinicariello, F., Hoffman, H., Deitchman, S., Radke, M., Themann, C., Breyse, P. (2017). Vital Signs: Noise-Induced Hearing Loss Among Adults – United States 2011-2012. *Centers for Disease Control and Prevention: Morbidity and Mortality Weekly Report*. 66(5) 139. <http://dx.doi.org/10.15585/mmwr.mm6605e3>

Hearing loss data from the 2011-2012 national health and nutrition examination survey is studied. The presence of audiometric notches was evaluated in adults aged 20-69 years. Results indicated that 24% of the adults studied had audiometric notches. One third of people who reported being exposed to loud noise at work had notches.

Ryan, A. F., Kujawa, S. G., Hammill, T., Le Prell, C., & Kil, J. (2014). Temporary and Permanent Noise-induced Threshold Shifts: A Review of Basic and Clinical Observations. *Otology & neurotology: official publication of the American Otological Society, American Neurotology Society [and] European Academy of Otology and Neurotology*, 37(8), e271–e275. <https://dx.doi.org/10.1097%2FMAO.0000000000001071>

Review of basic and clinical findings relevant to defining temporary threshold shifts and permanent threshold shifts. Broad review of scientific literature resulted in conclusions that verified the idea that humans are more sensitive to noise between 4 and 6 kHz frequencies. Biological aspects of damage to hearing system were reviewed and explained, including damage to cochlea hair cells and auditory neurons.

Basner, M., Babisch, W., Davis, A., Brink, M., Clark, C., Janssen, S., & Stansfeld, S. (2013). Auditory and non-auditory effects of noise on health. *Lancet (London, England)*, 383(9925), 1325–1332. [https://dx.doi.org/10.1016%2FS0140-6736\(13\)61613-X](https://dx.doi.org/10.1016%2FS0140-6736(13)61613-X)

Review of effects of noise. Topics discussed include occupational noise induced hearing loss, diagnosis of noise induced hearing loss, annoyance to noise, sleep disturbance, cognitive performance and others. Each section broadly summarizes the effect of noise, including general levels associated with the effect and the level of maturity of the scientific evidence for the effect.

Activity Interference

The following studies were reviewed for the Activity Interference topic:

Alvarsson, J. J., Nordström, H., Lundén, P., & Nilsson, M. E. (2014). Aircraft noise and speech intelligibility in an outdoor living space. *The Journal of the Acoustical Society of America*, 135(6), 3455–3462. <https://doi.org/10.1121/1.4874625>

This study evaluated the effect of aircraft noise on speech intelligibility in an outdoor living environment. Participants listened to recordings of aircraft noise and phonetically balanced

words in this outdoor setting, and the authors measured speech intelligibility at different background noise levels.

Bartels, S., Márki, F., & Müller, U. (2015). The influence of acoustical and non-acoustical factors on short-term annoyance due to aircraft noise in the field — The COSMA study. *Science of the Total Environment*, 538, 834–843. <https://doi.org/10.1016/j.scitotenv.2015.08.064>

Used hourly surveys of residents near a busy airport to analyze the relationship between noise level, activity disrupted, and annoyance to aircraft noise. Activities studied included speech communication, watching TV/listening to radio, relaxing, eating, and physical activity.

Berglund, B., Lindvall, T., & Schwela, D. H. (1999). *WHO Guidelines for Community Noise*. <https://apps.who.int/iris/handle/10665/66217>

Summarized existing research about a variety of noise topics, including speech interference. Intended to serve as a resource to local, regional, and national decision-makers on noise policy.

Hall, F. L., Taylor, S. M., & Birnie, S. E. (1985). Activity interference and noise annoyance. *Journal of Sound and Vibration*, 103(2), 237–252. [https://doi.org/10.1016/0022-460X\(85\)90236-6](https://doi.org/10.1016/0022-460X(85)90236-6)

Developed an event-based model that expressed the probability of activity interference or annoyance occurring at any given noise level and tested the model with data from sites in Ontario exposed to aircraft, road traffic, or train noise. Activity interference findings were based on surveys of residents. The study found that speech communication and sleep are activities that are correlated with annoyance to noise.

Kobayashi, M., Morimoto, M., Sato, H., & Sato, H. (2007). Optimum speech level to minimize listening difficulty in public spaces. *The Journal of the Acoustical Society of America*, 121(1), 251–256. <https://doi.org/10.1121/1.2382499>

Evaluated the optimum speech levels for speech communication in public spaces by using measures of listening difficulty as rated by study participants.

Lee, P. J., & Jeon, J. Y. (2011). Evaluation of speech transmission in open public spaces affected by combined noises. *The Journal of the Acoustical Society of America*, 130(1), 219–227. <https://doi.org/10.1121/1.3598455>

Tested the effect of combined noise sources on speech transmission. Participants were given listening tests with different combinations of background noise from a typical urban square, road traffic noise, and stationary and impulsive construction noise, and speech intelligibility was measured.

Maffei, L., Masullo, M., Alexeeva, N., Palmieri, U., & Senese, V. P. (2012). The Speech Intelligibility Aboard Metros in Different Running Conditions. *Acta Acustica United with Acustica*, 98(4), 577–587. <https://doi.org/10.3813/AAA.918539>

Investigated the influence of noise on speech intelligibility inside metro trains under two different driving conditions (tunnel straight route and tunnel curve).

Shimokura, R., & Soeta, Y. (2009). Evaluation of speech intelligibility of sound fields in passenger train compartments. *Acoustical Science and Technology*, 30(5), 379–382. <https://doi.org/10.1250/ast.30.379>

Evaluated the speech intelligibility of announcements from PA systems on a passenger train.

Annoyance

The following studies were reviewed for the Annoyance topic:

Bartels, S., Marki, F., Muller, U. (2015). The Influence of Acoustical and Non-Acoustical Factors on Short-Term Annoyance Due to Aircraft Noise in the Field — the COSMA Study. *Science of the Total Environment*, 538, 834. <http://dx.doi.org/10.1016/j.scitotenv.2015.08.064>

Field study investigated aircraft noise-induced short-term (i.e., within hourly intervals) annoyance in local residents near a busy airport. Study aimed at examining the contribution of acoustical and non-acoustical factors contributing to noise annoyance ratings. Results include explained variance metrics for different factors including acoustical factors, operations statistics, and personal situational factors.

Borsky, P. (1973). A New Field-Laboratory Methodology for Assessing Human Response to Noise. *NASA Contractor Report*, NASA CR-2221. Columbia University. Langley Research Center. <https://ntrs.nasa.gov/search.jsp?R=19730009397>

Review of effects of noise on humans, and proposal of new methodology for assessing human response to noise pollution. This paper includes a comparison of data from British and American aircraft noise annoyance surveys. Average percent highly annoyed response rates are presented for different ratings of fear or feelings of misfeasance for the aircraft operators or airports.

Fastl, H., Zwicker, E. (1999). *Psycho-Acoustics: Facts and Models*, Second Edition. Springer.

Comprehensive textbook representing collection of data describing the processing of sound by the human hearing system. This book includes quantitative relations between sound stimuli and auditory perception. Contains solutions of practical benefit for engineers and applications in research fields. One of the leading textbooks on the subject of psychoacoustics.

Fidell, S., Barber, D., Schultz, T. (1991). Updating a dosage–effect relationship for the prevalence of annoyance due to general transportation noise. *Journal of the Acoustical Society of America*, 89(1), 221. <https://doi.org/10.1121/1.400504>

Update of Schultz’s 1978 analysis with new data from surveys and studies performed in the 1970s and 1980s. Similar results to Schultz’s work are presented, including an average dose-response curve for noise and percent highly annoyed. It is noted that the 1978 relationship still provides a reasonable fit to the data despite the vast amount of new data included in this study.

Guski, R. (2017). The Increase of Aircraft Noise Annoyance in Communities: Causes and Consequences. *Proceedings of the 12th International Commission on Biological Effects of Noise (ICBEN) Congress on Noise as a Public Health Problem.*

http://www.icben.org/2017/ICBEN%202017%20Papers/Keynote04_Guski_4164.pdf

Keynote conference presentation on data indicating a rise in aircraft noise annoyance in communities at given L_{Aeq} values. The paper discusses several potential causes of this process including changing study methodologies, contextual changes, increases in number of aircraft movements, changes in fleet composition, and attitudinal changes.

Guski, R., Schreckenber, D., Schuemer, R. (2017). Guidelines for the European Region: A Systematic Review on Environmental Noise and Annoyance. *International Journal of Environmental Research and Public Health*, 14(12), 1539. <https://doi.org/10.3390/ijerph14121539>

Systematic review of the dose response relationship between noise and annoyance. Quantitative meta-analysis was performed on 57 studies along with other data received from study authors. Studies included in the analysis were acoustical and social survey studies linking noise exposure to standard annoyance responses. Results were tentative dose response relationships combining the data obtained from the literature review for air, rail, and road transportation.

Miedema, H., Oudshoorn, C. (2001). Annoyance from Transportation Noise: Relationships with Exposure Metrics DNL and DENL and Their Confidence Intervals. *Environmental Health Perspectives*, 109(4), 409. <https://doi.org/10.1289/ehp.01109409>

Presentation of model of the distribution of noise annoyance with the mean varying as a function of the noise exposure. Model is fitted to data from noise annoyance studies for aircraft, road traffic, and railways separately. Confidence intervals are provided for the resulting analysis. Noise metrics used for the curve fitting are DNL and DENL. Polynomial approximations of relationships implied by these models are presented as well.

Miller, M., Cantor, D., Lohr S., Jodts, E., Williams, D., et al. (2014). Research Methods for Understanding Aircraft Noise Annoyances and Sleep Disturbance. *The National Academies of Sciences Engineering and Medicine*. Transportation Research Board. <https://doi.org/10.17226/22352>

Research procedures for studying annoyance and sleep disturbance from aircraft noise. This includes surveys and survey procedures, as well as summaries of results from previous surveys. Metrics reported include response rates to different kinds of surveys, biases for different survey types and question types, and budgeting analyses for different survey types.

Pederson, T. H. (2007). The “Glenlyd” Noise Annoyance Model: Dose Response Relationships Modelled by Logistic Functions. *Summary Report for the Danish Ministry of Science, Technology, and Innovation*. https://assets.madebydelta.com/assets/docs/share/Akustik/The_Genlyd_Noise_Annoyance_Model.pdf

Summary of the dose-response model conceived by Danish research group for acoustics and electronics. This report includes a description of a nuanced functional model of annoyance that allows easier analysis of dose models. Also presented is a synthesis of dose response data and

curves from aircraft noise, roadway noise, railway noise, and wind turbine noise. Also discussed are non-acoustic factors that affect annoyance to noise, along with modifiers to model equations for these factors.

Schreckenber, D., Schuemer, R. (2010). The Impact of Acoustical, Operational and Non-Auditory Factors on Short-Term Annoyance due to Aircraft Noise. *39th International Congress on Noise Control Engineering, June 2010*. Lisbon, Portugal.

Re-analysis of data of the Frankfurt Noise Annoyance Study 2005 to identify acoustical, operational and non-acoustical factors contributing to the explanation of short-term annoyance (hourly annoyance). Statistical analysis results are indicated in terms of correlation factors, beta coefficients, and other metrics to determine which factors have higher relations to various annoyance ratings. Both attitudinal factors and activity interference are included as factors that affect short and long-term annoyance to aircraft noise.

Schultz, T. (1978). Synthesis of Social Surveys on Noise Annoyance. *Journal of the Acoustical Society of America*, 64(2), 377. <https://doi.org/10.1121/1.382013>

Review and synthesis of data from several social surveys on noise annoyance from different noise sources. Analysis results include an average curve derived from the annoyance data from 11 of the surveys reviewed. It is reported that it was the best currently available relationship for predicating community annoyance due to transportation noise at the time of writing.

Naim, F., Gulliver, J., Fecht, D., Hansell, A. (2017) Assessing the Relationship of Indoor and Outdoor Noise at Residential Dwellings in London. *12th International Commission on the Biological Effects of Noise Congress on Noise as a Public Health Problem, June 2017*. Zurich, Switzerland.

Exploration of indoor and outdoor noise levels to understand the relationship between the two. The study aims to assess how well outdoor noise levels predict indoor noise levels, as many epidemiological studies use outdoor noise levels to assess health impacts of noise. Continuous noise measurements were made inside and outside each measured residence for three consecutive days. Locations are grouped by primary noise sources, included aircraft, highways, railroads, etc.

Locher, B., Piquerez, A., Habermacher, M., Ragetti, M., Rösli, M., Brink, M., ... Wunderli, J. M. (2018). Differences between Outdoor and Indoor Sound Levels for Open, Tilted, and Closed Windows. *International journal of environmental research and public health*, 15(1), 149. <https://dx.doi.org/10.3390%2Fijerph15010149>

Study aimed at determining sound level differences between indoors and outdoors for different window positions, building locations, and building characteristics including age, construction material, etc. Linear regression models were developed relating the indoor L_{Aeq} and the outdoor L_{Aeq}

Health and Sleep Impacts

The following studies were reviewed for the Health and Sleep Impacts topic:

Basner, M., & McGuire, S. (2018). WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Effects on Sleep. *International Journal of Environmental Research and Public Health*, 15(3), 519. <https://doi.org/10.3390/ijerph15030519>

Systematic review of the effects of environmental noise exposure on sleep based on 74 studies conducted between 2000 and 2015. The study involved a meta-analysis of surveys linking road, rail, and aircraft noise exposure to self-reports of sleep disturbance. The study also involved a pooled analysis of polysomnographic studies on the acute effects of transportation noise on sleep.

Brown, A., & van Kamp, I. (2017). WHO Environmental Noise Guidelines for the European Region: A Systematic Review of Transport Noise Interventions and Their Impacts on Health. *International Journal of Environmental Research and Public Health*, 14(8), 873. <https://doi.org/10.3390/ijerph14080873>

Literature review of studies from 1980 to 2014 on evidence of the effects of transport noise interventions on human health. Transportation sources included road traffic, railways, and air traffic, and health outcomes included disturbance, annoyance, cognitive impairment of children, and cardiovascular diseases. Interventions included actions to change the noise exposure as measured at the external façade of the residence, and actions such as communication or education aimed at changing health outcomes but not people's exposure to noise. The analysis showed that many of the interventions were associated with changes in health outcomes irrespective of the source type, intervention type, or outcome measured.

Coggon, D., Rose, G., & Barker, D. (n.d.). *Epidemiology for the uninitiated* (4th Edition). Retrieved from <https://www.bmj.com/about-bmj/resources-readers/publications/epidemiology-uninitiated/8-case-control-and-cross-sectional>

Background resource on types of epidemiological studies, including case-control, cross sectional, and ecological studies.

Consensus Conference Panel, Watson, N. F., Badr, M. S., Belenky, G., Bliwise, D. L., Buxton, O. M., ... Heald, J. L. (2015). Joint Consensus Statement of the American Academy of Sleep Medicine and Sleep Research Society on the Recommended Amount of Sleep for a Healthy Adult: Methodology and Discussion. *Sleep*, 38(8), 1161–1183. <https://doi.org/10.5665/sleep.4886>

Summary of the findings and methodology for an American Academy of Sleep Medicine and Sleep Research Society Consensus Statement regarding the recommended amount of sleep to promote optimal health in adults.

Correia, A. W., Peters, J. L., Levy, J. I., Melly, S., & Dominici, F. (2013). Residential exposure to aircraft noise and hospital admissions for cardiovascular diseases: multi-airport retrospective study. *BMJ*, 347(oct08 3), f5561–f5561. <https://doi.org/10.1136/bmj.f5561>

Study investigates whether exposure to aircraft noise increases the risk of hospitalization for cardiovascular diseases in older people residing near airports. The study uses a dataset of approximately 6 million older people residing near 89 airports in the U.S., and noise contours provided by the FAA. Finds a statistically significant association between exposure to aircraft noise and risk of hospitalization for cardiovascular diseases among older people living near airports.

Miedema, H. M. E., & Vos, H. (2007). Associations Between Self-Reported Sleep Disturbance and Environmental Noise Based on Reanalyses of Pooled Data From 24 Studies. *Behavioral Sleep Medicine*, 5(1), 1–20. https://doi.org/10.1207/s15402010bsm0501_1

Study involves a re-analysis of pooled data from studies on the association between self-reported sleep disturbance and exposure to nighttime transportation noise. Develops functions that give the percentage highly sleep disturbed, sleep disturbed, and (at least) a little sleep disturbed people due to aircraft, road traffic, and railway noise in relation to the average nighttime outdoor exposure level at the facade most exposed to the source concerned.

Peters, J. L., Zevitas, C. D., Redline, S., Hastings, A., Sizov, N., Hart, J. E., ... Wellenius, G. A. (2018). Aviation Noise and Cardiovascular Health in the United States: a Review of the Evidence and Recommendations for Research Direction. *Current Epidemiology Reports*, 5(2), 140–152. <https://doi.org/10.1007/s40471-018-0151-2>

Review focuses on recent findings on the relationship between aircraft noise and cardiovascular outcomes (over the last five years) and directions for future research. Epidemiological studies generally report statistically significant associations between aircraft noise and adverse cardiovascular outcomes, although with limited evidence within the USA. Sleep disturbance, associated with nighttime noise, has been shown to be a risk factor for cardiovascular disease given associations with inflammatory markers and metabolic changes.

Somers, V. K., White, D. P., Amin, R., Abraham, W. T., Costa, F., Culebras, A., ... Young, T. (2008). Sleep Apnea and Cardiovascular Disease. *Journal of the American College of Cardiology*, 52(8), 686–717. <https://doi.org/10.1016/j.jacc.2008.05.002>

Describes the types and prevalence of sleep apnea and its relevance to individuals who either are at risk for or already have established cardiovascular disease.

Van Kempen, E., Casas, M., Pershagen, G., & Foraster, M. (2018). WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Cardiovascular and Metabolic Effects: A Summary. *International Journal of Environmental Research and Public Health*, 15(2), 379. <https://doi.org/10.3390/ijerph15020379>

Systematic review of the literature dealing with observational studies on the association between environmental noise exposure and the cardiovascular and metabolic systems. The article aims to update some of the existing exposure-response relationships, and to evaluate the overall quality of the evidence.

Cognitive Effects

The following studies were reviewed for the Cognitive Effects topic:

Clark, C., Head, J., & Stansfeld, S. A. (2013). Longitudinal effects of aircraft noise exposure on children's health and cognition: A six-year follow-up of the UK RANCH cohort. *Journal of Environmental Psychology*, 35, 1–9. <https://doi.org/10.1016/j.jenvp.2013.03.002>

Follow-up study to the RANCH study on noise exposure and cognition six years after the original data collection. The purpose of the study was to evaluate the long-term effects of aircraft noise exposure on children's learning and health.

Clark, C., Martin, R., Van Kempen, E., Alfred, T., Head, J., Davies, H. W., ... Stansfeld, S. A. (2006). Exposure-Effect Relations between Aircraft and Road Traffic Noise Exposure at School and Reading Comprehension. *American Journal of Epidemiology*, 163(1), 27–37. <https://doi.org/10.1093/aje/kwj001>

This study involved the evaluation of RANCH study data on noise exposure at school and cognition outcomes, combined with information on aircraft noise exposure at home. The study found no additional effect of aircraft noise exposure at home after adjustment for aircraft noise exposure at school.

Clark, C., & Paunovic, K. (2018). WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Cognition. *International Journal of Environmental Research and Public Health*, 15(2), 285. <https://doi.org/10.3390/ijerph15020285>

Review to assess the quality of evidence for the association between environmental noise exposure and cognition. Based on 34 studies, the review describes the effects of environmental noise on cognition across different noise sources and cognition outcomes, and assesses the quality of evidence for each combination of noise source and cognition outcome.

Guski, R., Klatter, M., Moehler, U., Müller, U., Nieden, A. zur, & Schreckenberger, D. (2016). *NORAH (Noise Related Annoyance, Cognition, and Health): Questions, designs, and main results.*

Study on the effects of chronic exposure to aircraft noise on the cognitive performance and quality of life of schoolchildren near Frankfurt Airport.

Hygge, S., Evans, G. W., & Bullinger, M. (2002). A Prospective Study of Some Effects of Aircraft Noise on Cognitive Performance in Schoolchildren. *Psychological Science*, 13(5), 469–474. <https://doi.org/10.1111/1467-9280.00483>

Before/after study on the association between noise and cognition when a new airport opened in Munich and led to changes in noise exposure at schools near the new and old airports.

Klatte, M., Bergström, K., & Lachmann, T. (2013). Does noise affect learning? A short review on noise effects on cognitive performance in children. *Frontiers in Psychology*, 4. <https://doi.org/10.3389/fpsyg.2013.00578>

Literature review on the pathways through which noise affects children's learning. Includes information on the effects of noise on speech interference, non-auditory tasks, and cognitive development.

Matsui, T., Stansfeld, S., Haines, M., & Head, J. (2004). Children's cognition and aircraft noise exposure at home--the West London Schools Study. *Noise & Health*, 7(25), 49–58.

This study examined the effects of noise exposure at home on children's cognitive performance. The study involved students attending schools near London's Heathrow Airport where noise exposure at school and at home differed.

National Academies of Sciences, Engineering, and Medicine 2014. *Assessing Aircraft Noise Conditions Affecting Student Learning, Volume 1: Final Report*. Washington, DC: The National Academies Press. <https://doi.org/10.17226/22433>.

Nationwide study at schools near 46 airports in the U.S. The purpose of the study was to identify the relationship between aircraft noise exposure and student performance, taking into account the effect of school sound insulation and other confounding factors.

Stansfeld, S. A., Berglund, B., Clark, C., Lopez-Barrio, I., Fischer, P., Öhrström, E., ... Berry, B. F. (2005). Aircraft and road traffic noise and children's cognition. *The Lancet*, 366(9487), 715–716. [https://doi.org/10.1016/S0140-6736\(05\)67174-7](https://doi.org/10.1016/S0140-6736(05)67174-7)

Describes the methodology and results of the RANCH study, a cross-national, cross-sectional study of the effects of aircraft and road traffic noise on children's learning in the Netherlands, Spain and the United Kingdom.

Financial Impacts

The following studies were reviewed for the Financial Impacts topic:

Almer, C., Boes, S., and Nüesch, S. (2017). Adjustments in the housing market after an environmental shock: evidence from a large-scale change in aircraft noise exposure. *Oxford Economic Papers*. <https://doi.org/10.1093/oenp/gpw071>

Evaluated apartment rents around Zurich airport before and after a change in aircraft noise due to changing flight patterns. Found that apartment rents in areas exposed to more aircraft noise decreased for two years, then stabilized at a lower equilibrium.

Brandt, S., & Maennig, W. (2011). Road noise exposure and residential property prices: Evidence from Hamburg. *Transportation Research Part D: Transport and Environment*, 16(1), 23–30. <https://doi.org/10.1016/j.trd.2010.07.008>

Used hedonic regression models to examine the effects of road noise on condominium prices in city of Hamburg, Germany. Found price discounts of 0.23% following a 1 dB(A) increase in road noise, and that price discounts depend on the noise level (higher for higher noise levels).

McMillen, D. P. (2004). Airport expansions and property values: the case of Chicago O'Hare Airport. *Journal of Urban Economics*, 55(3), 627–640. <https://doi.org/10.1016/j.jue.2004.01.001>

Used transaction data to estimate the effect of airport noise on property values around Chicago O'Hare airport. The results indicated that home values were about 9% lower within a 65 dB noise contour band of O'Hare in 1997.

Nelson, J. P. (1980). Airports and Property Values: A Survey of Recent Evidence. *Journal of Transport Economics and Policy*, 14(1), 37–52.

Literature review of hedonic regression studies on the impact of aviation noise on residential property values. Found that aviation noise has a negative impact on property values, ranging from 0.4 to 1.1% per dB of noise increase.

Nelson, J. P. (1982). Highway Noise and Property Values: A Survey of Recent Evidence. *Journal of Transport Economics and Policy*, 16(2), 117–138.

Literature review of hedonic regression studies on the impact of highway noise on residential property values. Found that highway noise has a negative impact on property values, of approximately 0.4% per dB of noise increase.

Ozdenerol, E., Huang, Y., Javadnejad, F., & Antipova, A. (2015). The Impact of Traffic Noise on Housing Values. *Journal of Real Estate Practice and Education*, 18(1), 35–54.

Evaluated the impact of traffic noise on property prices in Shelby County, TN using a hedonic regression model. Found that traffic noise, in general, has a significantly negative impact on housing values, and that the discount on housing values increases as the noise nuisance levels increase.

Theebe, M. (2004). Planes, Trains, and Automobiles: The Impact of Traffic Noise on House Prices. *Journal of Real Estate Finance and Economics*, 28(2/3), 209–234.

Estimated the impact of mixed traffic noise on property prices near Schiphol airport in Amsterdam using sales transactions and noise data for 100m by 100m areas. Found a non-linear relationship between traffic noise and housing prices, with an average of about a 5 percent discount.

Walker, J. K. (2016). Silence is Golden: Railroad Noise Pollution and Property Values. *The Review of Regional Studies*, 45, 75–89.

Used a dataset containing property values and manually collected noise measurements in Memphis, Tennessee to estimate the impact of train noise pollution on commercial and residential property values. Results showed that locations within the 65 dB contour resulted in a 14 to 18 percent decrease in residential property value.

Impulse Noise

The following studies were reviewed for the Impulse Noise topic:

Brink, M. & Wunderli, J.-M. (2010). A field study of the exposure-annoyance relationship of military shooting noise, *Journal of the Acoustical Society of America*, 127, 2301, <https://doi.org/10.1121/1.3337234>

This article reported a field study on noise annoyance from military shooting with small, midsize, and heavy weapons that was carried out among residents living near eight different training grounds of the Swiss army. Results are varied, with a 5-point annoyance scale more closely relating to noise exposure and sound exposure level relating most to variations in annoyance.

Fidell, S., Pearsons, K. (Feb. 1994). Comparison of Methods of Predicting Community Response to Impulsive and Nonimpulsive Noise. *NASA Ames Research Center, High-Speed Research: Sonic Boom*, Volume 1, 177-189

Examination and review of methods of predicting community response to both impulse and non-impulse noise. This includes derivation of dosage-response relationships from a few different data sources including Schultz in the 1970s and CHABA data sources. Conclusions specify that impulsive noise is more complex and that fewer data exists than for general transportation noise

Fidell, S., Pearsons, K. (Oct. 1994). Deriving a dosage-response relationship for community response to high-energy impulsive noise. *1994 NASA Sonic Boom Workshop: Atmospheric Propagation and Acceptability Studies*, 185-192

Mathematical exercise utilizing existing data sets and a curve fitting method to derive dosage response relationship for high-energy impulse noise to community annoyance. Conclusions indicate that CDNL with a response bias correction factor produces a better fitting curve than previously obtained.

Fields, J.M. (1997). Reactions of Residents to Long-Term Sonic Boom Noise Environments. *NASA Final Contractor Report*, <https://ntrs.nasa.gov/search.jsp?R=19970023685>

Report of a combined social survey and noise measurement program for 14 communities in the western U.S. (Nevada). The 6 month study is one of the main sonic boom research programs referenced today is part of the overall data set in this subject.

Maglieri, D., Bobbit, P., Plotkin, K., Shepherd, K., Coen, P., Richwine, D., (2014). Sonic Boom: Six Decades of Research. *NASA Langley Research Center*, <https://ntrs.nasa.gov/search.jsp?R=20150006843>

Large-scale synthesis on all subjects surrounding sonic booms. Section on response to sonic boom was reviewed in depth. Generally, the data varies enough that conclusions are difficult to make. However, it is clear from the research that shaped sonic booms can have a large impact on community response to sonic boom exposure.

Page, J., Hodgdon, K., Krecker, P., Cowart, R., Hobbs, C., Wilmer, C., Koenig, C., Holmes, T., Gaugler, T., Shumway, D. (2014). Waveforms and Sonic Boom Perception and Response (WSPR): Low-Boom Community Response Program Pilot Test Design, Execution, and Analysis. *NASA Technical Report, Langley Research Center*, <https://ntrs.nasa.gov/search.jsp?R=20140002785>

Large-scale study using Edwards AFB and surrounding communities on response to sonic boom exposure. Correlations and dose response relationships are studied for different assessment metrics.

Price, G.R., (2010). Auditory Hazard Assessment Algorithm for Humans (AHAH). *U.S. Army Research Laboratory, Model Website*, <https://www.arl.army.mil/www/default.cfm?page=343>

Website on U.S. Army Research Laboratory site with a few articles detailing the development and verification process for the AHAH model. Articles reviewed include the executive summary, cat exposure studies, and functional descriptions of the model.

Ryalander, R., Lundquist, B. (1996). Annoyance Caused by Noise from Heavy Weapon Shooting Ranges. *Journal of Sound and Vibration*, 192, 1, 199-206, <https://doi.org/10.1006/jsvi.1996.0183>

Survey based study in Switzerland studying annoyance to heavy weapon shooting ranges. Results are compared to earlier similar studies and exposure-response is related to the number of noise events exceeding 90 dB L_{cx} (C-weighted sound pressure level averaged over 1 second).

Starck, J., Toppila E., Pyykko, I. (2003). Impulse noise and risk criteria. *Noise and Health Journal*. 5:63-73. <http://www.noiseandhealth.org/text.asp?2003/5/20/63/31687>

Review of national risk criteria and available standards, studies, and data on the risk of damage from impulse noise. Discusses industrial impulse noise as well as shooting noise as a risk of hearing impairment. Specifies that international risk assessment methodologies need to be developed.

Lie, A., Skogstad, M., Johannessen, H. A., Tynes, T., Mehlum, I. S., Nordby, K. C., ... Tambs, K. (2016). Occupational noise exposure and hearing: a systematic review. *International archives of occupational and environmental health*, 89(3), 351–372. <https://dx.doi.org/10.1007%2Fs00420-015-1083-5>

Systematic literature review of occupational noise studies, specifically focusing on the effect of noise exposure on hearing. Gives quantitative results for overall occupational noise exposure. For impulse noise, concludes that effects seem to be more deleterious than for continuous noise.

Stationary Sources

Murphy, E., King, E. (2014). Environmental Noise Pollution: Noise Mapping, Public Health, and Policy. *Elsevier Inc*. Chapter 6, Industrial and Construction Type Noise, 173. <https://doi.org/10.1016/C2012-0-13587-0>

Textbook on addressing the key debates surrounding environmental noise pollution with focus on the European Union. The authors used their considerable research experience in this field in this benchmark reference across disciplinary, policy, and national boundaries. Chapter 6 includes

discussions of multiple non-transportation noise sources including windmills, industrial sites, construction sites, and quarries.

Thomas, G., Liu, Y. (2013). Cowal Gold Mine Extension Modification Noise and Blasting Impact Assessment. *SLR Consulting Australia Ltd.* Report number 610.10052-R1.

Noise impact assessment relating to proposed modifications to an existing gold mine in New South Wales. The assessment included measurements of existing ambient noise levels, and modeling of resulting noise levels from specific mining activities. Modeled noise level increases in residential areas surrounding the mine are given, including those from blasting operations. Noise levels resulting from changes to road traffic volumes were also modeled.

Benchmark Resources. (2011). Moody Flats Quarry Project Environmental Impact Report: Noise Impact Analysis. *Benchmark Resource with Shasta County Department of Resource Management, 19005 Placer Street, Suite 103, Redding, CA, 96001*

Noise impact assessment for installation of a quarry in Shasta County, California. The assessment was performed to model the project's impact on environmental noise levels on surrounding areas. Compliance with county standards was examined as well. The analysis included measurement of ambient noise levels in the area as well as modelled sound levels resulting from project implementation.

Bansah, K. J., Bosompem, A. (2015). Predicting the Levels of Noise from Quarry Operations. *24th International Mining Congress and Exhibition of Turkey, April 14-17, 2015. Antalya, Turkey.*
<https://doi.org/10.13140/rg.2.1.4122.5201>

Study on the impacts of mining activities on the sounding noise environment for a quarry in Ghana. Notable among these impacts is noise emission from sources such as machinery, drilling, blasting, dumping and crushing. 25 days of monitoring was conducted for 24 hours each day. The noise from different activities was modelled at different receiver locations. Some recommendations are given to reduce the levels of noise generated at the quarry.

Mendocino County, CA, Code of Ordinances. Ch. 22.16 – Surface Mining and Reclamation, Section 070: Permit Operational Standards. (2017).
<https://www.conservation.ca.gov/smgb/reports/Documents/Ordinances-County/Mendocino.pdf>

Standards for operating surface mines. Stipulates noise standards at the receiver for surface mining operations. Overall, this policy provides regulations for all surface mining operations in Mendocino County, CA.

Urman, S. (1987). A Survey of Railroad Occupational Noise Sources. *Transportation Research Board. Transportation Research Record 1143. National Research Council, Washington, D.C.*

Measured noise levels are presented for various railroad industry noise sources, including railroad classification yards, locomotives, and cabooses. Alternative control methods for sound reduction are outlined.

Oriel, A. (2017). Lawsuit Rails against train yard's deafening noise levels. Sandusky Register. Retrieved from <http://www.sanduskyregister.com/story/201703170035>

Article detailing a lawsuit filed by residents living nearby a railyard in Bellevue, Ohio. Residents complained of high noise levels, squeals from retarders, and a lack of regard on the part of the operator for the effect the yard had on surroundings.

European Commission Working Group on Assessment of Exposure to Noise (WG-AEN). (2007). Good Practice Guide for Strategic Noise Mapping and the Production of Associated Data on Noise Exposure, Version 2.

Position paper aimed at helping member states of the EU undertake noise mapping and produce the associated data as required by Directive 2002/49/EC of the European Parliament. Contains discussions and recommendations for noise source, propagation and receiver related issues. Also provides discussion on modeling toolkits and the accuracy thereof. Provides default values of sound power levels for industrial sites.

van den Berg, M. Van den Burg, M. (1999). Industry Data. Retrieved from <https://rigolett.home.xs4all.nl/GV/kenind.htm> and translated using google translate.

Database of default values of noise produced by different types of industrial areas. Averages are given in sound power decibels per meter squared and can be adjusted based on the lot size of the industrial site.

Berkeley California Community Noise Standards. (2009). Berkeley, CA, USA. City Clerk, Title 13 Chapter 13.40. <https://www.codepublishing.com/CA/Berkeley/html/pdfs/Berkeley13.pdf>

Standards and regulations defining community noise limits, times of day when noise-generating activities are acceptable, and abatement criteria. The goals of the regulation are to limit the number of intrusive, offensive, and excessive noises that occur in the city of Berkeley, CA.

Heibel, J., Durkay, J. (2016). State Legislative Approaches to Wind Energy Facility Siting. Retrieved from <http://www.ncsl.org/research/energy/state-wind-energy-siting.aspx> National Conference of State Legislatures.

Discussion and list of legislative approaches to wind energy facility siting regulations in different states. Currently available regulations, standards, or recommendations are tabulated and compared.

ESS Group, Inc. (2010). Sound Survey and Analysis Report: Proposed Wind Energy Facility in the Town of Brewster Massachusetts. Cape and Vineyard Electric Cooperative, Inc. https://www.rd.usda.gov/files/UWP_MA01-CVEC_Brewster_EA-App4.pdf

Predicted noise levels from full operation of the proposed wind energy facility were evaluated with respect to applicable state and local noise regulations for both high wind speed conditions and low wind speed conditions. Operational noise is assessed at the property line of the proposed facility and at the closest noise-sensitive land use in the surrounding community.

Page, J., Solman, G., Stahl, L. (2018). Commercial Space Launch Noise and Sonic Boom Research Roadmap. *Volpe National Transportation Systems Center, for the Federal Aviation Administration*. Internal report not published.

Overview of the burgeoning area of space development, including the commercial business landscape and the state of the art of space vehicles from a community noise perspective. Examines models relevant to space launch noise, and gives some modeled noise results in appendices for specific space launch situations.

Bradley, K. A., James, M. M., Salton A. R., Boeker, E. R. (2018). Commercial Space Operations Noise and Sonic Boom Modeling and Analysis. *National Academies of Sciences, Engineering, and Medicine. The National Academies Press*. <https://doi.org/10.17226/25100>.

Report detailing the development of a rocket noise and sonic boom model for commercial space operations that can be integrated with FAA's Aviation Environmental Design Tool. A database was developed of existing vehicle/engine data to be used for modeling purposes. The resulting models are based on the rocket noise model "RUMBLE" and the sonic boom model "PCBoom."



2025 Annual Report for Noise Camera Enforcement Program **Pursuant to Local Law 7 of 2024**

Background

Noise emissions from loud vehicle engines or mufflers can impinge on the quality of life in New York City. Some vehicle noise is so loud that it can even be a source of harmful public health impacts, such as sleep deprivation and hearing loss. In recent years, complaints about loud vehicle engines and mufflers have increased. The Department of Environmental Protection's Noise Camera Enforcement Program was created to combat this excessive noise. With strategically placed noise cameras, the Department ("DEP") identifies vehicles that exceed the New York City Noise Code's limits. A summons can be issued to any vehicle found to be violating these limits using evidence gathered by the camera.

Local Law 7

Local Law 7 of 2024 mandates a noise camera program that detects motor vehicles exceeding noise limits under the Noise Code. Subject to appropriations, DEP must install no fewer than five noise cameras in each borough by September 2025. In 2025, DEP had twelve cameras and has not received appropriations to expand the program.

Overview of the Program

The noise cameras are comprised of an array of microphones and cameras, including a "fisheye" (panoramic) and license plate reader (LPR) camera. When the microphones detect that a certain noise threshold is exceeded, the fisheye camera pinpoints the source of noise by placing a red dot on the source. Using the photo of the license plate that is captured by the LPR camera, the owner of the vehicle can be identified. Then, a summons for engine/muffler noise can be issued by DEP staff. Summonses for engine and muffler noise are issued pursuant to section 24-236(e) of the Noise Code. However, DEP not only uses the noise cameras to address engine/muffler noise but also uses them to address horn honking under section 24-237(a) and music from vehicles under section 24-233(b). The summonses are returnable at the NYC Office of Administrative Trials and Hearings (OATH.) If found in violation at OATH, civil penalties are imposed against the vehicle owner.

Annual Report

Pursuant to section 24-236.1(e) of the Noise Code, DEP is required to submit to the Mayor and the Speaker of the Council, and to post on its website, an annual report on the program including:

1. The locations of any such photo noise violation monitoring devices and time periods during which such devices were used;
2. The total number of violations recorded by photo noise violation monitoring devices on a daily, weekly, and monthly basis;
3. The total number of notices of violation issued for violations recorded by such devices;

4. The total number of violations (summonses) adjudicated in accordance with subchapter 8 of this chapter and the results of such adjudications, disaggregated by dispositions made for violations recorded by such devices; and
5. Any expenses incurred by the city in connection with the program.

Reported Data

Location Number	Camera Location	Dates Deployed	Dates camera was inactive or date of removal at the location	Number of summonses issued at this location (filed at OATH)	Number of Events Captured at the location
1	2698 Bailey Avenue, Bronx, NY 10463	1/1/2025 - 11/19/25	Under maintenance 11/19/25-12/31/25	77	1,195
2	1469 Saint Nicholas Avenue, New York, NY 10033	1/1/2025 - 12/31/2025		208	1,569
3	150 West 65th Street, New York, NY 10023	1/1/2025 - 12/31/2025		126	1,781
4	210 East 36th Street, New York, NY 10016	1/1/2025 - 12/31/2025		701	3,329
5	25-45 Borden Avenue, Long Island City, NY 11101	1/1/2025 - 12/31/2025		210	1,299
6	2601 Ocean Parkway, Brooklyn, NY 11235	1/1/2025 - 5/28/2025	Under maintenance 5/28/2025-12/31/2025	30	409
7	36-11 20th Avenue, Long Island City, NY 11105	1/1/2025 - 2/9/2025	Removed 2/9/2025	7	12

Location Number	Camera Location	Dates Deployed	Dates camera was inactive or date of removal at the location	Number of summonses issued at this location (filed at OATH)	Number of Events Captured at the location
8	510 West 41st Street, New York, NY 10018	1/1/2025 - 12/31/2025		211	3,074
9	6700 3rd Avenue, Brooklyn 11220	1/1/2025 - 1/5/25	Removed 1/5/2025	32	32
10	110 Tillary Street, Brooklyn 11201	10/1/2025 - 12/31/2025		17	1,673
11	1209 Viele Avenue, Bronx 10474	8/4/2025 - 12/3/2025	Under maintenance 12/3/2025-12/31/2025	67	1,552
12	98-05 63 Drive Rego Park 11374	4/25/2025 - 5/26/2025	Removed 5/26/2025	4	48
13	99-18 64 Avenue, Rego Park 11374	8/4/2025 - 10/31/2025	Under maintenance 10/31/2025-12/31/2025	1	21

Totals (All Locations)

There were 1,691 Summonses issued in 2025. There were 15,994 events. Therefore, 11%, resulted in summonses, with only 1.2% of the summonses dismissed at OATH. The number of summonses issued daily was 4.6 summonses; 33 summonses were issued on a weekly basis; and 141 summonses were issued on a monthly basis in CY 2025.

Adjudications in 2025

CY 2025 Dispositions (12 cameras)	CY 2025 Summonses (Filed at OATH)
Defaulted	965
New Issuance/Rescheduled	290
In Violation	214
Stipulated	12
Adjourned	14
Dismissed	20
Admit/In Violation	176

Note: Summonses issued during a calendar year may not be adjudicated within the same calendar year.

Expenses Incurred by the City

Below is a summary of the program’s personnel costs for CY 2025. Below is a summary of the vendor costs for CY 25.

Personnel Costs, Calendar Year 2025

Staffing: 2 Senior Inspectors, 6 Inspectors, 1 Administrative Manager

Total Personnel Cost: \$492,565

Vendor Costs for Calendar Year 2025

The Noise Camera Enforcement Program has partnered with Intelligent Instruments Ltd. to provide equipment, calibration, and service for the noise camera systems. Below is a summary of DEP’s costs for equipment and services provided by Intelligent Instruments Ltd.

Vendor costs for Calendar Year 2025

CY25	Calibration and Service for Noise Cameras	\$ 109,092
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City Revenue

For Calendar Year 2025, the penalties imposed amounted to \$1,472,265 and the amount paid was \$308,229.

‘Noise cameras’ aim to address vehicle nuisance complaints on city streets

Aftermarket vehicle exhaust systems are a noisy nuisance on some streets and intersections. Cities are trying new technology to pinpoint the problem and, in one city, ticket the offenders.

Published Feb. 15, 2023

By Dan Rosenbaum



Getty Images

Loud vehicles with modified exhaust systems meeting up at downtown intersections or speeding down city streets late at night are an increasing source of resident complaints in some communities. Many jurisdictions have laws against loud cars, trucks, and motorcycles, but identifying and catching violators has been challenging. Noise cameras promise to make that process simpler. However, the politics and laws surrounding noise cameras can be complex.

One supplier of the devices is the Southampton, UK-based Intelligent Instruments, which makes and sells the SoundVue system. The \$27,000 device (plus software licensing fees), roughly the size of a large suitcase, attaches to a light pole and can be easily moved from location to location, the company says. Reuben Peckham, a director at Intelligent Instruments, said London has about a dozen of its devices installed, and the company has received inquiries from more than 30 U.S. cities.

Carter Hall, policy and business innovation manager for Knoxville, Tennessee, said his city has one noise camera downtown that gathers data about the scope of the vehicular noise problem. “We think of it more as a kind of engineering survey tool, the way that you would [study] traffic patterns, but to understand noise violation,” Hall said. A [local news report](#) from July 2022 said that about 1,300 cars had triggered the camera in roughly the first six months of operation.

“At the time, there were only two other cities in the world that were using these cameras: London and then New York,” Hall said.

For Knoxville, issuing tickets for noise violations would be complicated, Hall said, and would need to start with action by the Tennessee state legislature. “We don’t do vehicle inspections here, where some states do their muffler checking, so that’s not a tool available to us.” Hall said police can issue noise citations for excessive noise at parties using body camera evidence and wondered if there were a way to apply that to vehicles, noting that it might require new or amended legislation.

“A lot of times when I talk to [other] cities, I used to just be allowed to talk about the camera and the technology,” Hall said. “But now, a lot of my conversations now are about how do you think about your city codes and your ordinances so that you can actually

enforce things. You know, you've got to have a legal framework that lets you do these important things.”

New York addressed the problem in 2021 when the state enacted the SLEEP Act, which increased penalties for driving or selling vehicles with altered exhaust systems to \$1,000. Mechanics who make the alterations can lose their state licenses to perform inspections.

New York City appears to be the only U.S. city issuing citations for vehicle noise complaints captured by a noise camera. Its one device has been moved to five different locations since its deployment in mid-2021. Douglas Auer, a spokesperson for the city's Department of Environmental Protection, says it has issued 71 citations since then and expects to deploy a second camera this month.

“The noise camera is equipped with a high-definition camera and audio sensor that are triggered by cars and other vehicles that exceed pre-defined noise limits,” Auer said. “The sound meter and camera are installed adjacent to the roadway and are activated when they detect a noise at a distance of 50 feet or more that registers at or above 85 dBA.” He said inspectors and supervisors screen each video before DEP issues a citation.

The citations — \$800 for a first offense, rising to \$2,500 for a third offense — are civil penalties. They trigger administrative hearings and do not put the driver's license or registration at risk. The city's Office of Administrative Trials and Hearings records show that few of the cited drivers appear for a hearing, and many citations have gone unpaid.

SLEEP Act sponsor Sen. Andrew Gournades said he would introduce a bill this year that would authorize noise cameras statewide. “The solution here is to strengthen enforcement and strengthen penalties, but also shift to an automated enforcement

model, which we know is more objective, more fair, and takes law enforcement directly out of their responsibility,” Gournades said.

In Knoxville, “from the outset, we were very clear that the noise camera is not a silver bullet for us,” Hall said. “It’s just a way to gain information. But I am hopeful that pretty soon we will be able to implement some things that will get us closer to mitigation and enforcement going hand in hand.”

SENATE JUDICIARY COMMITTEE
Senator Thomas Umberg, Chair
2021-2022 Regular Session

SB 1079 (Portantino)
Version: March 29, 2022
Hearing Date: May 3, 2022
Fiscal: No
Urgency: No
CK

SUBJECT

Vehicles: sound-activated enforcement devices

DIGEST

This bill authorizes pilot programs in six cities to evaluate the use of sound-activated devices to enforce vehicle noise limit laws.

EXECUTIVE SUMMARY

This bill seeks to address the issue of noise pollution in California cities that is caused by illegally modified or otherwise out of compliance exhaust systems. Following the lead of a handful of cities in other states and countries, this bill authorizes pilot programs in six cities to deploy and evaluate the use of sound-activated devices to capture vehicle noise levels that exceed the legal sound limit set by the Vehicle Code in connection with exhaust systems.

The pilot can extend for five years in the participating cities and a report is required to be compiled and submitted to the Legislature evaluating the effectiveness of the pilot program.

This bill is sponsored by Streets for All. It is supported by various cities and organizations, including the City of Santa Monica and the California Contract Cities Association. It is opposed by Safer Streets LA as well as several privacy and consumer groups, including the Electronic Frontier Foundation. This bill passed out of the Senate Committee on Transportation Committee on a 12 to 1 vote.

PROPOSED CHANGES TO THE LAW

Existing law:

- 1) Requires every motor vehicle equipped with an internal combustion engine and subject to registration to be equipped at all times with an adequate muffler in constant operation and properly maintained to prevent any excessive or unusual noise, and no muffler or exhaust system shall be equipped with a cutout, bypass, or similar device. (Veh. Code § 27150.)
- 2) Prohibits a person from modifying the exhaust system of a motor vehicle in a manner which will amplify or increase the noise emitted by the motor of the vehicle so that the vehicle is not in compliance with the provisions of Section 27150 or exceeds the noise limits established for the type of vehicle in Article 2.5 (commencing with Section 27200). A person is prohibited from operating a motor vehicle with an exhaust system so modified. (Veh. Code § 27151(a).)
- 3) Provides that for the purposes of exhaust systems installed on motor vehicles with a manufacturer's gross vehicle weight rating of less than 6,000 pounds, other than motorcycles, a sound level of 95 dbA or less, when tested in accordance with Society of Automotive Engineers Standard J1492 October 2008, complies with the above requirement. Motor vehicle exhaust systems or parts thereof include, but are not limited to, nonoriginal exhaust equipment. (Veh. Code § 27151(b).)

This bill:

- 1) Authorizes six unnamed cities to conduct a pilot program to evaluate the use of sound-activated enforcement devices to capture vehicle noise levels that exceed the legal sound limit. The bill leaves blank the person or entity that will name the cities authorized to participate.
- 2) Requires the pilot program to abide by the following guidelines:
 - a) must operate from January 1, 2023, to December 31, 2027, inclusive;
 - b) sound-activated enforcement devices must be distributed equally across a participating city and cannot be disproportionately placed in a single area or areas;
 - c) prior to reaching the sound-activated enforcement device, a sign shall be placed to notify motorists of the device's existence;
 - d) prohibits a city from imposing a penalty for a first violation but requires the city to impose a penalty for subsequent violations;
 - e) requires a city to consider a person's ability to pay the penalty and allow payment of the penalty in installments or deferred payment if the person provides satisfactory evidence of an inability to pay the penalty in full;

- f) requires a participating city to adopt regulations allowing a penalty waiver for a low-income motor vehicle owner, as defined; and
 - g) the sound-activated enforcement devices must each undergo an annual calibration check performed by an independent calibration laboratory, which shall issue a signed certificate of calibration. The participating city shall keep the annual certificate of calibration on file.
- 3) Requires that revenues derived from the utilization of a sound-activated enforcement device first be used by the participating city to recover the costs of the program, and may also be used for traffic calming measures, including, but not limited to, bicycle lanes, chicanes, chokers, curb extensions, median islands, raised crosswalks, road diets, roundabouts, speed humps or speed tables, and traffic circles.
 - 4) Requires information collected and maintained by a city using a sound-activated enforcement device to be confidential and to only be used to administer the program. Such information cannot be disclosed to any other persons, including, but not limited to, any other state or federal government agency or official for any other purpose, except as required by state or federal law, court order, or in response to a subpoena in an individual case or proceeding.
 - 5) Requires a participating city to destroy images collected under this pilot program upon the final resolution of the notice of violation.
 - 6) Defines a “sound-activated enforcement system” as an electronic device that utilizes automated equipment that activates when the noise levels have exceeded the legal sound limit and is designed to obtain a clear photograph of a vehicle license plate.
 - 7) Provides that participating cities shall, no later than December 31, 2026, prepare and submit a report to the Legislature evaluating and determining the effectiveness of the pilot program.

COMMENTS

1. A brief history of automated Vehicle Code enforcement

While some counties may have installed automated traffic enforcement systems at an earlier date, legislative authorization for automated enforcement procedures relating to traffic violations began in 1994 with SB 1802 (Rosenthal, Ch. 1216, Stats. 1994). That bill authorized the use of “automated rail crossing enforcement systems” to enforce prohibitions on drivers from passing around or under rail crossings while the gates are closed. (Veh. Code § 22451.) Those systems functioned by photographing the front license plate and the driver of vehicles who proceeded around closed rail crossing gates

in violation of the Vehicle Code provisions. The drivers of photographed vehicles, in turn, received citations for their violations.

In 1995, the Legislature authorized a three-year trial for red light camera enforcement programs. (SB 833, Kopp, Ch. 922, Stats. 1995.) Using similar technology, that program used sensors connected to cameras to take photographs of the front license plate and driver upon entering an intersection on a red light. That program was permanently extended in 1998 by SB 1136 (Kopp, Ch. 54, Stats. 1998).

In 2007, the Legislature authorized a four-year pilot project where San Francisco was authorized to install video cameras on city-owned public transit vehicles for the purpose of video imaging parking violations occurring in transit-only traffic lanes. (AB 101, Ma, Ch. 377, Stats. 2007.) Three years later, the Legislature authorized a five-year statewide pilot project to allow local public agencies to use automated parking enforcement systems for street sweeping-related violations. (AB 2567, Bradford, Ch. 471, Stats. 2010.)

In 2011, the Legislature extended San Francisco's automated transit-only lane enforcement program for an additional year, and required the City and County to provide a report to the Transportation and Judiciary Committees of the Legislature no later than March 1, 2015, describing the effectiveness of the pilot program and its impact on privacy. (AB 1041, Ma, Ch. 325, Stats. 2011.) Following the receipt of that report, San Francisco's transit-only lane enforcement program was permanently extended in AB 1287 (Chiu, Ch. 485, Stats. 2015).

The following year, SB 1051 (Hancock, Ch. 427, Stats. 2016) authorized AC Transit to operate an automated transit-only lane enforcement program similar to San Francisco's with a sunset on January 1, 2022. AC Transit was required to provide to the Transportation, Privacy and Consumer Protection, and Judiciary Committees of the Legislature an evaluation report of the enforcement system's effectiveness, impact on privacy, cost to implement, and generation of revenue, no later than January 1, 2021. (Veh. Code § 40240.5.) Just last year, AB 917 (Bloom, Ch. 709, Stats. 2021) authorized all public transit operators to install these automated forward-facing cameras on transit vehicles for the purposes of enforcing parking violations occurring in transit-only traffic lanes and at transit stops and stations.

Additional legislation, including SB 371 (Caballero, 2019), SB 111 (Newman, 2021), and AB 2084 (Jones-Sawyer, 2022), have been introduced that would allow for automated video traffic enforcement on the outside of school buses. SB 735 (Rubio, 2021) would have authorized local authorities to place "speed photoimaging enforcement devices" to enforce speed limits in school zones. AB 2336 (Friedman, 2022) authorizes a five-year speed safety system pilot program, from 2023 to 2028, in San Jose, Oakland, Los Angeles, Glendale, one unspecified Southern California city, and San Francisco to

enforce speed limits through automated devices on no more than 15 percent of their streets.

2. Introducing sound enforcement

This bill adds to the growing number of avenues where automated enforcement is taking the place of traditional law enforcement. The goal is to address the particular instance of noise pollution, where individuals modify their exhaust systems to unlawfully loud levels. Every motor vehicle equipped with an internal combustion engine and subject to registration must be equipped at all times with an adequate muffler in constant operation and properly maintained to prevent excessive or unusual noise. The law prohibits a muffler or exhaust system to be equipped with a cutout, bypass, or similar device. (Veh. Code § 27150.)

Specifically, the law prohibits a person from modifying the exhaust system of a motor vehicle in a manner which will amplify or increase the noise emitted by the motor of the vehicle so that the vehicle is not in compliance with the above provision or exceeds the noise limits established for the type of vehicle, as specified. A person is prohibited from operating a motor vehicle with an exhaust system so modified. (Veh. Code § 27151(a).) For example, for exhaust systems installed on motor vehicles with a manufacturer's gross vehicle weight rating of less than 6,000 pounds, other than motorcycles, compliance means a sound level of 95 dbA or less. This level is comparable to that of a power mower.

Law enforcement has expressed frustration with their ability to enforce such laws:

California Highway Patrol Officer Dan Olivos echoes law enforcement agencies throughout Southern California – including Laguna Beach – when he details the challenges and intricacies of controlling illegal exhaust systems.

First, there's an array of what's OK and what's not, depending on the year a motorcycle was built. Second, what qualifies as a proper muffler is vague.

California vehicle code 27150 states, "Every motor vehicle (shall be) equipped with an adequate muffler in constant operation and properly maintained to prevent any excessive or unusual noise."

But one person's excess is another's pleasure.

Additionally, the California Bureau of Automotive Repair states motorcycles manufactured in or after 2013 must have the federal

Environmental Protection Agency noise emission label. The penalty for no label amounts to a fix-it ticket.

In reality, it's the wild west when it comes to exhaust systems.

Very few officers are trained or have decibel meters and – unlike with radar guns – are left guessing about noise levels.

“What we base our judgment on,” Olivos explains, “is whether it sounds like it should when it comes off the showroom floor.”

Much of the problem is that these hobbyists like to tinker with their vehicles. Some go so far as to modify exhaust systems in a misguided attempt to impress or annoy.

It has gotten so bad in recent years, that California has had to enact laws that prohibit such things as “cutouts,” “bypasses” and something called a “whistle-tip.”¹

This bill allows up to six cities to implement a pilot program to use “sound-activated enforcement devices” to capture vehicle noise levels that exceed the legal sound limit set by Vehicle Code section 27151. The program will run from January 1, 2023, to December 31, 2027, and participating cities are required to submit a report to the Legislature at the end of the program evaluating its effectiveness.

According to the author:

Illegally loud exhaust harms our bodies, can be deafening if you are walking or cycling on a street, and wakes people up from their sleep. While vehicle exhaust noise is limited to 95 decibels, there is no universal means to monitor and enforce this law. Vehicle owners can easily buy and install new exhaust systems or make other modifications to their vehicle that will change the level of sound. SB 1079 will permit 6 cities or counties, to be determined later, to address illegal noise violations in their community by using decibel-measuring tools and noise activated cameras.

A number of cities have written in support of the bill requesting to be among the six authorized to participate in the pilot. The City of Santa Monica writes:

¹ David Whiting, *Illegal mufflers are roaring as loud as airplanes, but law enforcement crackdown is difficult* (June 29, 2018) The Orange County Register, <https://www.ocregister.com/2018/06/29/illegal-mufflers-are-roaring-as-load-as-airplanes-but-law-enforcement-crackdown-is-difficult/>. All internet citations are current as of April 28, 2022.

Noise pollution is an unwanted or disturbing sound that causes adverse reactions for humans and other living creatures. Loud noises in the street can disrupt walking or cycling, but also can cause hearing loss and pose dangers to physical and cognitive health. Exposure to loud sounds has been shown to raise levels of stress hormones, including cortisol, adrenaline, and noradrenaline. Chronically high levels of these hormones can impact heart disease, hypertension, stroke, immune responses, and cognitive functioning.

Under the California Vehicle Code, exhaust noise is limited to 95 decibels (dbA) for vehicles and 80 dbA for motorcycles. However, vehicle owners can install new exhaust systems or make other vehicle modifications that change the level of sound produced by their vehicle. These illegal modifications are accessible and easily installed at any in-home garage, resulting in much louder noise disruptions than would be allowed by law.

SB 1079 will provide cities with an enforcement tool that will help crack down on these noisily modified vehicles and motorcycles that adversely impact our resident's quality of life.

The City of Laguna Beach writes in support:

A majority of loud vehicle noise comes from willful violations of existing Vehicle Code that makes it a crime to modify the exhaust system of a vehicle for the purpose of increasing or amplifying noise emitted by the vehicle. The City has previously partnered with neighboring cities to educate the public and conduct joint enforcement exercises to reduce loud vehicle noise. Allowing local jurisdictions to create, operate, and manage their own sound-activated enforcement device program would help address loud vehicle noise issues.

The author points to examples in New York, Knoxville, and Paris where similar devices are being used and Toronto and Philadelphia where they are being considered.

3. Concerns with this iteration of automated enforcement

This Committee has previously expressed a series of concerns whenever automated traffic enforcement programs are sought to be implemented and has sought to build in protections when such enforcement is deemed appropriate. These concerns involve the privacy implications of such methods and the issues of fairness and equity inherent in the program, especially when such enforcement creates a revenue stream for a governmental entity. Whenever automation is involved, ensuring due process is afforded to ticketed residents is critical. In all instances, this Committee has urged

caution and any further extension of automated enforcement should be thoughtful, incremental, and with thorough reporting requirements.

a. The fundamental right to privacy

The California Constitution provides that all people have inalienable rights, including the right to pursue and obtain privacy. (Cal. Const., art. I, Sec. 1.) This Committee has previously expressed concern about the privacy implications of using automated enforcement, especially when continuous surveillance is an element of said enforcement.

The bill does provide some privacy protections. Information collected and maintained by a city using a sound-activated enforcement device is deemed confidential. The bill includes use limitations, authorizing the data to only be used to administer the program. Further disclosure is prohibited, including to other state and federal government agencies and officials for any other purpose. The only exception is where it is required by state or federal law, court order, or in response to a subpoena in an individual case or proceeding. Retention is limited and all images collected must be destroyed upon the final resolution of the notice of violation.

These are certainly crucial baseline protections for this systematic data collection. However, the programs will inherently be surveilling these communities. While the exact technology is not spelled out in the bill, the technology used elsewhere involves a continually running video feed. The bill does not provide for how these cameras should be situated or whether they need to limit their focus to avoid continually capturing more than the vehicles they are seeking to monitor. These issues have been raised in the context of automated license plate readers as well.

Although disclosure is limited, it is not implausible that these feeds could be subjected to regular subpoenas seeking their footage. The author may wish to consider adding in protections for exactly how long video footage can be kept.

In addition, while the provision making data confidential helps protect individuals' privacy, it may impair the transparency of the program. A number of groups in opposition highlight the need for transparency into these programs.

Safer Streets LA asserts that "the bill makes all information captured by the systems confidential, even administrative data such as how many people are being ticketed and at what sound levels etc. This bill ensures there will be *zero* government transparency and accountability."

Similarly, the Electronic Frontier Foundation writes:

[W]hile SB 1079 purports to limit the use of this technology in various ways, we see no obvious way in which misuse or abuse of the technology would be detectable or enforced. Not only is there no enforcement of these limits in SB 1079, we worry that the confidentiality requirement of proposed Vehicle C. § 27150.4 (c) would make it very easy for government to withhold its knowledge of such abuses from the public.

b. Equity, fairness, and basic due process

The bill attempts to address concerns regarding equity and fairness with a number of provisions.

First, sound-activated enforcement devices are required to be distributed equally across a participating city and not disproportionately placed in a single area or areas. The aim is to avoid exacerbating the issue of overly policed and punished communities. However, Oakland Privacy argues that while such provisions are critical they need to be bolstered in order to ensure they are effectuated in practice:

This is an important measure for economic equity, but without a public use policy, how will we know what a local jurisdiction's interpretation of "equally" works out to in practice? It is likely not every street in a jurisdiction will be equipped, and the choices about where to place this equipment and when should be explained, justified and be subject to public feedback. We point to last year's AB 550 as a similar measure that included use policy creation by the jurisdiction and believe the requirement for a public use policy should be a part of this proposal. The use policy should provide the jurisdiction's plan for compliance with all of the requirements listed in AB 1079, along with customary information about data retention, storage and security, including vendor policies.

Relatedly, the impact of these systems is consistently and disproportionately felt by lower income communities. The bill does provide for this to be taken into consideration through the requirement that a city consider a person's ability to pay the penalty and allow payment of the penalty in installments or deferred payment if the person provides satisfactory evidence of an inability to pay the penalty in full. In addition, participating cities are required to adopt regulations allowing a penalty waiver for low-income motor vehicle owners. But the exact details of what this must entail are left vague.

With regard to fairness and adequate due process, automated enforcement needs to have a high level of certainty in its determination that the relevant law has been broken, there must be a clear and effective process for appealing such determinations, and the

public must have sufficient notice and be subject to reasonable penalties. On these last points, focus must arguably be on promoting roadway safety, as the creation of a new stream for revenue generation might affect the fairness and equity of a program. Here the bill provides that a sign must be placed to notify motorists of the sound-activated device's existence prior to reaching the sound-activated enforcement device. However, some concerns have been raised about the lack of specificity here. In addition, the bill restricts a city from imposing a penalty for the first violation, but then requires a penalty for subsequent violations.

As for revenue derived from the utilization of a sound-activated enforcement device, the bill provides that it must first be used by the participating city to recover the costs of the program created pursuant to this section, but then allows it to be used for traffic calming measures, including, but not limited to, bicycle lanes, chicanes, chokers, curb extensions, median islands, raised crosswalks, road diets, roundabouts, speed humps or speed tables, and traffic circles.

One concerning absence in the bill is the lack of specificity on the type of technology that can be used and the level of accuracy these devices provide. A "sound-activated enforcement system" is simply defined as an "electronic device that utilizes automated equipment that activates when the noise levels have exceeded the legal sound limit and is designed to obtain a clear photograph of a vehicle license plate." In other contexts, the use of video or photographs depicts the violation itself. Here, the violation is connected to sound and a photograph that is thereafter taken. While the bill requires annual calibration checks, the ultimate issue is not only whether the device consistently triggers at a certain decibel threshold, but that the sound is coming from a specific vehicle in violation of the relevant Vehicle Code provisions.

Reasonable questions are raised about how such technology can differentiate between vehicles in busy roadways, one of the target environments for enforcement, or how the devices can differentiate between sound emanating from a vehicle's muffler versus other nearby causes, such as construction. Even basic elements of these systems are unknown and not spelled out in the bill, such as how the device even identifies where sound is coming from or where the camera would be situated.

If a motorist receives a violation, what would be the basis for challenging such a citation? What evidence is accessible to the motorist? Where a picture may show a vehicle in an intersection after a red light or a car parked in a bus lane, a photograph of a license plate does not inherently establish a violation of a noise provision specific to mufflers.

It is also unclear at what decibel level the device must be calibrated. For motorcycles, the limit is 92 dbA if manufactured before 1970, but 80 dbA if after 1985. The periods in between are at varying levels. For motor vehicles, the limit is based on a matrix of weight and date of manufacture. For the purposes of exhaust systems installed on

motor vehicles with a manufacturer's gross vehicle weight rating of less than 6,000 pounds, other than motorcycles, a sound level of 95 dbA or less is in compliance.

These details should arguably be established and the accuracy of these systems ensured before motorists are subject to financial penalties.

The author may wish to limit these pilot projects to collecting more information about the accuracy of the technology and simply provide warnings to drivers rather than subject them to infractions without first testing these systems out. One lesson is taken from a similarly narrow pilot done in Edmonton:

The community and public services committee report summarizes efforts to collect data on the use of specialized noise monitoring equipment as well as trends in vehicle noise, planned in two phases during the summers of 2019 and 2020.

Part of that included testing automated noise monitoring technologies cycled between nine locations from July to September 2020.

The equipment was able to detect and record audio levels and video when noise thresholds were broken.

But the technology couldn't tell the difference between sources of noise or identify offending vehicles to the precision required by court.

"It's concerning that it's not as accurate as we would hope for," Coun. Jon Dziadyk, the committee's vice-chair, said Monday.

Administration's goal was to identify when best to deploy enforcement personnel, according to the report. Peace officers were also sent to verify the information and identify offending vehicles.

Only one instance resulted in enforcement being taken. Peace officers spent 150 hours at or near targeted enforcement locations.²

² *Edmonton noisy vehicle enforcement pilot sees mixed results* (February 16, 2021) CBC News, <https://www.cbc.ca/news/canada/edmonton/edmonton-noisy-vehicle-enforcement-pilot-sees-mixed-results-1.5914862>.

4. Stakeholder concerns

Safer Streets LA emphasizes the equity concerns:

[W]e are very concerned about the equity issues implicated by this new technology. How can we be assured that only those who are flagrantly violating the law by modifying their exhaust systems are targeted and not low-income working-class vehicle owners who might simply be driving an older vehicle and not have the means to upgrade? How do we ensure that those who are incorrectly ticketed (as no technology is perfect) can be made whole after having to expend time and money defending themselves against a ticket issued in error?

ACLU California Action echoes a concern of other groups in opposition that this bill opens the door to more widespread use of problematic technology:

The text of the bill is vague about what technologies and tech vendors would be authorized, but it would appear to permit the use of ShotSpotter-like sound-activated technologies.³ Like many others, we question the accuracy and fairness of ShotSpotter,⁴ a major vendor of such noise-activated enforcement technology, and have joined privacy organizations calling for serious scrutiny of claims made by its vendors.⁵ A MacArthur Justice Center report on the use of ShotSpotter in Chicago, for example, found that “ShotSpotter imposes a massive additional burden of unfounded and unnecessary police deployments – but only in the predominantly Black and Latinx districts where it is deployed[,]”⁶ and initial police responses to 88.7% of ShotSpotter alerts found no incidents involving a gun.⁷ A highly critical report by the Chicago Office of the Inspector General (OIG) found that Chicago “police responses to ShotSpotter alerts rarely produce evidence of a gun-related crime, rarely

³ “ShotSpotter is gunshot detection, acoustic surveillance technology that uses sophisticated sensors to detect, locate and alert law enforcement agencies of illegal gunfire incidents in real time.” *ShotSpotter Frequent Asked Questions*, ShotSpotter, available at https://www.shotspotter.com/system/content/uploads/ShotSpotter_FAQ_June_2017.pdf.

⁴ See, for example, Jay Stanley, *Four Problems with the ShotSpotter Gunshot Detection System*, ACLU (August 24, 2021), available at <https://www.aclu.org/news/privacy-technology/four-problems-with-the-shotspotter-gunshot-detection-system>.

⁵ Matthew Guariglia, *It’s Time for Police to Stop Using ShotSpotter*, Electronic Frontier Foundation (July 29, 2021), available at <https://www.eff.org/deeplinks/2021/07/its-time-police-stop-using-shotspotter>.

⁶ *ShotSpotter is deployed overwhelmingly in Black and Latinx neighborhoods in Chicago*, MacArthur Justice Center, available at <https://endpolicesurveillance.com/burden-on-communities-of-color/>.

⁷ Jay Stanley, *Four Problems with the ShotSpotter Gunshot Detection System*, ACLU (August 24, 2021), available at <https://www.aclu.org/news/privacy-technology/four-problems-with-the-shotspotter-gunshot-detection-system>.

give rise to investigatory stops, and even less frequently lead to the recovery of gun crime-related evidence during an investigatory stop.”⁸

SUPPORT

Streets for All (sponsor)
California Contract Cities Association
California Police Chiefs Association
City of Hayward
City of Laguna Beach
City of San Diego
City of Santa Monica

OPPOSITION

ACLU California Action
Electronic Frontier Foundation
Oakland Privacy
Safer Streets LA

RELATED LEGISLATION

Pending Legislation:

AB 2084 (Jones-Sawyer, 2022) *See* Comment 1.

AB 2336 (Friedman, 2022) *See* Comment 1.

Prior Legislation:

SB 111 (Newman, 2021) *See* Comment 1.

SB 735 (Rubio, 2021) *See* Comment 1.

AB 550 (Chiu, 2021) would have authorized a pilot program for automated speed enforcement in several cities in California. This bill died in the Assembly Appropriations Committee.

AB 917 (Bloom, Ch. 709, Stats. 2021) *See* Comment 1.

SB 371 (Caballero, 2019) *See* Comment 1.

⁸ Joseph M. Ferguson, *The Chicago Police Department’s Use of Shotspotter Technology*, City of Chicago Office of Inspector General (August 2021), available at <https://igchicago.org/wp-content/uploads/2021/08/Chicago-Police-Departments-Use-of-ShotSpotter-Technology.pdf>.

SB 1079 (Portantino)

Page 14 of 14

AB 1051 (Hancock, Ch. 427, Stats. 2016) *See Comment 1.*

AB 1287 (Chiu, Ch. 485, Stats. 2015) *See Comment 1.*

AB 1041 (Ma, Ch. 325, Stats. 2011) *See Comment 1.*

AB 2567 (Bradford, Ch. 471, Stats. 2010) *See Comment 1.*

AB 101 (Ma, Ch. 377, Stats. 2007) *See Comment 1.*

SB 1136 (Kopp, Ch. 54, Stats. 1998) *See Comment 1.*

SB 833 (Kopp, Ch. 922, Stats. 1995) *See Comment 1.*

SB 1802 (Rosenthal, Ch. 1216, Stats. 1994) *See Comment 1.*

PRIOR VOTES:

Senate Transportation Committee (Ayes 12, Noes 1)

CHAPTER 347

EQUIPMENT OF VEHICLES

	SUBCHAPTER I		
	GENERAL PROVISIONS		
347.01	Words and phrases defined.	347.29	Display of warning devices for certain vehicles when standing on highway.
347.02	Applicability of chapter.	347.30	Penalty for violating lighting equipment requirements.
347.03	Sale of prohibited equipment unlawful.		SUBCHAPTER III
347.04	Owner responsible for improperly equipped vehicle.		OTHER EQUIPMENT
347.05	Reciprocity agreements as to equipment.		
	SUBCHAPTER II		
	LIGHTING EQUIPMENT		
347.06	When lighted lamps required.	347.35	Brakes.
347.07	Special restrictions on lamps and the use thereof.	347.36	Performance ability of brakes.
347.08	Determining the visibility distance and mounted height of lamps.	347.37	Brake fluid, sale regulation.
347.09	Headlamps on motor vehicles.	347.38	Horns and warning devices.
347.10	Headlamp specifications for motor vehicles other than mopeds and motor bicycles.	347.385	Traffic control signal preemption and priority devices.
347.11	Headlamp specifications for mopeds and motor bicycles.	347.39	Mufflers.
347.115	Modulating headlamps for motorcycles, motor bicycles or mopeds.	347.40	Mirrors.
347.12	Use of multiple-beam headlamps.	347.41	Speed indicators.
347.13	Tail lamps and registration plate lamps.	347.413	Ignition interlock device tampering; failure to install.
347.14	Stop lamps.	347.415	Odometer tampering.
347.145	Deceleration warning lights for motorcycles, motor bicycles, mopeds or motor buses.	347.417	Immobilization device tampering.
347.15	Direction signal lamps or devices.	347.42	Windshield wipers.
347.16	Clearance lamps and reflectors.	347.43	Safety glass.
347.17	Color of clearance and marker lamps and reflectors.	347.435	Vehicle monitoring and feedback.
347.18	Mounting of clearance lamps and reflectors.	347.44	Painting requirements for school buses; restrictions as to painting of other vehicles.
347.19	Visibility of clearance lamps and reflectors.	347.445	Crossing gates for school buses.
347.20	Lamp or flag on projecting load or fixture.	347.446	Audiovisual recording on school buses.
347.21	Lamps and flags on trains of agricultural vehicles.	347.447	Additional safety mirrors on school buses.
347.22	Lamps on farm tractors, self-propelled implements of husbandry, and lightweight utility vehicles.	347.45	Tire equipment.
347.23	Lamps on highway maintenance equipment.	347.455	Modifications to height of vehicle.
347.24	Lamps and reflectors on nonmotor vehicles and equipment.	347.46	Fenders and mudguards.
347.245	Identification emblem on certain slow moving vehicles.	347.47	Drawbars, trailer hitches and mobile home couplings.
347.25	Special warning lamps on vehicles.	347.475	Airbags, prohibited practices.
347.26	Restrictions on certain optional lighting equipment.	347.48	Safety belts and child safety restraint systems.
347.27	When lighted lamps required on parked vehicles.	347.485	Protective headgear for use on motorcycles.
347.28	Certain vehicles to carry flares or other warning devices.	347.486	General requirements.
		347.487	Seating requirements.
		347.488	Moped equipment.
		347.489	Lamps and other equipment on bicycles and other vehicles and devices.
		347.49	Equipment of vehicles transporting flammable liquids.
		347.495	Registration plate concealment device.
		347.50	Penalties.

Cross-reference: See also ch. [Trans 305](#), Wis. adm. code.

SUBCHAPTER I

GENERAL PROVISIONS

347.01 Words and phrases defined. Words and phrases defined in s. [340.01](#) are used in the same sense in this chapter unless a different definition is specifically provided.

347.02 Applicability of chapter. (1) No provision of this chapter requiring vehicles to be equipped in a particular manner is applicable to any of the following vehicles unless the vehicle is expressly included within or made subject to the particular provision:

- (a) Farm tractors.
- (b) Implements of husbandry.
- (c) Vehicles drawn by animals.
- (d) Road machinery.
- (e) Bicycles.
- (em) Electric bicycles.
- (g) Motor bicycles.
- (h) Golf carts operated in accordance with s. [349.18 \(1\) \(b\)](#) or (c) or [\(1m\)](#).
- (i) Electric scooters and electric personal assistive mobility devices.
- (j) Lightweight utility vehicles, as defined in s. [346.94 \(21\) \(a\) 2](#).

(k) Personal delivery devices.

(2) No provision of this chapter requiring or prohibiting certain types of equipment on a vehicle is applicable when such vehicle is not operated upon or occupying a highway.

(2m) (a) No provision of this chapter requiring or prohibiting certain types of equipment on a vehicle is applicable to an imported vehicle which has been granted entry into the United States by the federal government solely for the purpose of test or experiment.

(b) The exemption under par. (a) is limited to the one-year period following the entry of the vehicle.

(3) Nothing in this chapter shall be construed to prohibit the use of additional parts and accessories on any vehicle not inconsistent with this chapter.

(4) Beginning July 1, 1960, the provisions of this chapter covering lighting shall be applicable to all state, county and municipal trucks, truck tractors, trailers and semitrailers.

(5) If a vehicle registered under s. [341.25 \(1\) \(a\)](#), [341.265](#), [341.266](#), or [341.269](#) has equipment which was designated by the manufacturer as optional equipment in the model year the vehicle was manufactured, it is not necessary for such equipment to be in operating condition unless it replaces equipment which is required by law to be both present and functioning.

(6) Notwithstanding the requirements of this chapter, the department may establish special equipment standards for vehicles operated under s. [343.135](#) which differ from the equipment standards established under this chapter. Equipment standards estab-

347.02 EQUIPMENT OF VEHICLES

Updated 23-24 Wis. Stats. 2

lished under this subsection may not be less stringent than any federal standards established for the vehicle.

(7) The vehicle equipment requirements for a street modified vehicle shall be the same as the vehicle equipment requirements for a vehicle of the same type and model year that is not a street modified vehicle. The vehicle equipment requirements for a replica vehicle or a homemade vehicle specified in s. 341.268 (1) (b) 2. shall be the same as the vehicle equipment requirements for a vehicle of the same type and model year as the vehicle used for purposes of the reproduction.

(8) If the department establishes by rule limitations on the tinting of motor vehicle windows, the limitations do not apply to police vehicles owned by the state or a county, city, village, or town when tinting is necessary for the protection of personnel, passengers, or equipment.

History: 1977 c. 39; 1979 c. 345; 1981 c. 275; 1983 a. 243, 288, 538; 1985 a. 187; 1985 a. 197 s. 7; 1993 a. 165; 1997 a. 27; 1999 a. 85; 2001 a. 90, 109; 2009 a. 135, 157; 2013 a. 20; 2015 a. 232; 2017 a. 13; 2019 a. 11, 34; 2023 a. 251.

347.03 Sale of prohibited equipment unlawful. No person shall sell for highway use any device, appliance, accessory or replacement part the use of which on a motor vehicle is unlawful.

347.04 Owner responsible for improperly equipped vehicle. Any owner of a vehicle not equipped as required by this chapter who knowingly causes or permits such vehicle to be operated on a highway in violation of this chapter is guilty of the violation the same as if he or she had operated the vehicle personally. No demerit points shall be assessed or counted pursuant to s. 343.32 against the operator's license of the owner of the vehicle by reason of the owner's conviction of any such violation unless the owner was personally operating the vehicle at the time of the violation.

History: 1989 a. 105.

347.05 Reciprocity agreements as to equipment. (1) The secretary, with the approval of the governor, is authorized to enter into reciprocal agreements with the duly authorized representatives of other jurisdictions exempting the residents of those jurisdictions from details of vehicle equipment requirements of this state which are particularly burdensome to residents of such other jurisdictions operating vehicles in this state, provided the law of such other jurisdiction requires vehicles to be equipped in a manner rendering them substantially as safe as those equipped in the manner required by the laws of this state. The agreements shall provide substantially like exemptions for residents of this state when operating vehicles in such other jurisdiction.

(2) This section does not authorize reciprocity agreements as to laws governing the size and weight of vehicles.

History: 1977 c. 29 s. 1654 (7) (c).

SUBCHAPTER II

LIGHTING EQUIPMENT

347.06 When lighted lamps required. (1) Except as provided in subs. (2) and (4), no person may operate a vehicle upon a highway during hours of darkness or during a period of limited visibility unless all headlamps, tail lamps, and clearance lamps with which the vehicle is required to be equipped are lighted. Parking lamps as described in s. 347.27 may not be used for this purpose. This subsection does not apply if lamps that are automatically activated whenever the vehicle is started are in use, if the headlamps are of sufficient intensity to satisfy the requirements for daytime running lamps under 49 CFR 571.108, S7.10.13.

(2) Headlamps need not be lighted on a towed vehicle or on a

vehicle having at least 2 lighted adverse weather lamps on the front thereof and being operated under the circumstances described in s. 347.26 (3) (b).

(3) The operator of a vehicle shall keep all lamps and reflectors with which such vehicle is required to be equipped reasonably clean and in proper working condition at all times.

(4) A duly authorized warden, as defined in s. 24.01 (11), may operate a vehicle owned or leased by the department of natural resources upon a highway during hours of darkness or during a period of limited visibility without lighted headlamps, tail lamps, or clearance lamps in the performance of the warden's duties under s. 29.924 (2).

History: 1977 c. 425; 1979 c. 32; 1981 c. 98 s. 3; 1997 a. 248; 2015 a. 165; 2017 a. 365.

347.07 Special restrictions on lamps and the use thereof. (1) Whenever a motor vehicle equipped with headlamps also is equipped with any adverse weather lamps, spotlamps or auxiliary lamps, or with any other lamp on the front thereof projecting a beam of intensity greater than 300 candlepower, not more than a total of 4 of any such lamps or combinations thereof on the front of the vehicle shall be lighted at any one time when such vehicle is upon a highway.

(2) Except as provided in sub. (3), or as otherwise expressly authorized or required by this chapter, no person shall operate any vehicle or equipment on a highway which has displayed thereon:

(a) Any color of light other than white or amber visible from directly in front; or

(b) Any color of light other than red on the rear; or

(c) Any flashing light.

(3) A motorcycle may be equipped with a lighting device that illuminates the ground directly beneath the motorcycle if all of the following apply:

(a) The lighting device is not visible to approaching vehicles.

(b) The lighting device does not display a red, blue, or amber light.

(c) The lighting device does not display a flashing, oscillating, or rotating light.

History: 2015 a. 27.

347.08 Determining the visibility distance and mounted height of lamps. (1) Whenever this chapter states a requirement as to distance from which certain lamps and devices shall render objects visible or within which such lamps or devices shall be visible, such distance shall be measured during hours of darkness under normal atmospheric conditions and upon a straight, level, unlighted highway unless a different time, direction or condition is expressly stated.

(2) Whenever this chapter requires a lamp or device to be mounted at a certain height, the distance shall be measured from the center of the lamp or device to the level ground upon which the vehicle stands when such vehicle is without load.

(3) Whenever this chapter requires a lamp or device to be mounted at a certain height, the distance shall be measured from the center of the lamp or device to the level ground upon which the vehicle stands when such vehicle is without load.

347.09 Headlamps on motor vehicles. (1) No person may operate a motor vehicle on a highway during hours of darkness or during a period of limited visibility, unless the vehicle is equipped as follows:

(a) Except as provided in pars. (b) and (c), every motor vehicle shall be equipped with at least 2 headlamps, which headlamps shall comply with the requirements and limitations set forth in sub. (2) and s. 347.10 and shall be mounted symmetrically with respect to the vertical plane extending through the longitudinal axis of the vehicle with at least one on each side of the center of the front of the motor vehicle.

(b) Every moped or motorcycle shall be equipped with at least

3 Updated 23-24 Wis. Stats.**EQUIPMENT OF VEHICLES****347.13**

one and not more than 2 headlamps, which headlamps shall comply with the requirements and limitations set forth in sub. (2) and s. 347.10.

(c) Every motor bicycle or vehicle registered under s. 341.067 and operated by a person licensed under s. 343.075 or 343.135 shall be equipped with at least one and not more than 2 headlamps, which headlamps shall comply with the requirements and limitations set forth in sub. (2) and s. 347.11.

(2) Every headlamp on a motor vehicle shall be located at a height of not more than 54 inches nor less than 24 inches.

History: 1983 a. 243; 1985 a. 65; 2015 a. 165; 2019 a. 50.

Cross-reference: See also ss. Trans 305.11, 305.43, and 305.55, Wis. adm. code.

347.10 Headlamp specifications for motor vehicles other than mopeds and motor bicycles. (1) Except as provided in sub. (4), the headlamps or the auxiliary driving lamp or the auxiliary passing lamp or combination thereof on motor vehicles other than mopeds and motor bicycles shall be so arranged that the driver may select at will between distributions of light projected to different elevations. No such lamp shall have any type of decorative covering that restricts the amount of light emitted when the lamp is in use. Such lamps may, in addition, be so arranged that such selection can be made automatically. This subsection does not apply to any type of decorative covering originally equipped on the vehicle at the time of manufacture and sale.

(2) Multiple-beam headlamps shall comply with the following requirements:

(a) There shall be an uppermost distribution of light or composite beam so aimed and of such intensity as to reveal persons and vehicles at a distance of at least 350 feet ahead for all conditions of loading;

(b) There shall be a lowermost distribution of light or composite beam so aimed and of sufficient intensity to reveal persons and vehicles at a distance of at least 100 feet ahead, and on a straight level road under any condition of loading none of the high-intensity portion of the beam shall be so directed as to strike the eyes of an approaching driver.

(3) No person shall sell after July 1, 1958, any new motor vehicle equipped with multiple beam headlamps and no person shall operate any motor vehicle sold new after July 1, 1958, and equipped with multiple beam headlamps unless such vehicle also is equipped with a beam indicator which is lighted whenever the uppermost distribution of light from the headlamps is in use and which is not otherwise lighted. Such indicator shall be so designed and located that when lighted it will be readily visible without glare to the driver of the vehicle so equipped. This subsection does not apply to motorcycles.

(4) Any motor vehicle may be operated during hours of darkness or during a period of limited visibility when equipped with 2 lighted lamps upon the front of the motor vehicle capable of revealing persons and objects 75 feet ahead in lieu of lamps required by subs. (1) to (3) if the vehicle at no time is operated at a speed in excess of 20 miles per hour. No lighted lamp under this subsection may have any type of decorative covering that restricts the amount of light emitted when the lighted lamp is in use. This subsection does not apply to any type of decorative covering originally equipped on the vehicle at the time of manufacture and sale.

History: 1983 a. 243; 1995 a. 346; 2015 a. 165.

Cross-reference: See also ss. Trans 305.11, 305.43, and 305.55, Wis. adm. code.

347.11 Headlamp specifications for mopeds and motor bicycles. The headlamps on mopeds or motor bicycles may be of the single-beam or multiple-beam type but in either event shall comply with the following requirements and limitations:

(1) The headlamp shall be an electric headlamp and the current shall be supplied by a wet battery and electric generator, by a current-generating coil incorporated into the magneto or by a generator driven directly by the motor by means of gears, friction wheel, chain or belt.

(2) The headlamp shall display a white light of sufficient illuminating power to reveal any person, vehicle or substantial object at a distance of 200 feet ahead and shall be so adjusted or operated that the glaring light rays therefrom are not directed into the eyes of the driver of any oncoming vehicle. No headlamp shall have any type of decorative covering that restricts the amount of light emitted when the headlamp is in use. This subsection does not apply to any type of decorative covering originally equipped on the vehicle at the time of manufacture and sale.

(3) If the moped or motor bicycle is equipped with a multiple-beam headlamp, the upper beam shall meet the minimum requirements set forth in sub. (2) and the lowermost beam shall meet the requirements applicable to a lowermost distribution of light as set forth in s. 347.10 (2) (b).

(4) If the moped or motor bicycle is equipped with a single-beam lamp, such lamp shall be so aimed that when the vehicle is loaded none of the high-intensity portion of light, at a distance of 25 feet ahead, projects higher than the level of the center of the lamp from which it comes.

History: 1983 a. 243; 1995 a. 346.

347.115 Modulating headlamps for motorcycles, motor bicycles or mopeds. A motorcycle, motor bicycle or moped may be equipped with and use a means of modulating the upper beam of the headlamp between a high and a lower brightness at a rate of 200 to 280 changes per minute. A headlamp may not be modulated during hours of darkness.

History: 1981 c. 52; 1983 a. 243.

347.12 Use of multiple-beam headlamps. (1) Whenever a motor vehicle is being operated on a highway during hours of darkness or during a period of limited visibility, the operator shall use a distribution of light or composite beam directed high enough and of sufficient intensity to reveal a person or vehicle at a safe distance in advance of the vehicle, subject to the following requirements and limitations:

(a) Whenever the operator of a vehicle equipped with multiple-beam headlamps approaches an oncoming vehicle within 500 feet, the operator shall dim, depress or tilt the vehicle's headlights so that the glaring rays are not directed into the eyes of the operator of the other vehicle. This paragraph does not prohibit an operator from intermittently flashing the vehicle's high-beam headlamps at an oncoming vehicle whose high-beam headlamps are lit.

(b) Whenever the operator of a vehicle equipped with multiple-beam headlamps approaches or follows another vehicle within 500 feet to the rear, the operator shall dim, depress, or tilt the vehicle's headlights so that the glaring rays are not reflected into the eyes of the operator of the other vehicle. This paragraph does not prohibit an operator from intermittently flashing the vehicle's high-beam headlamps as provided under par. (a).

(2) Subsection (1) (a) and (b) does not apply to the use of alternately flashing or pulsating headlamps under s. 347.25 (1r).

History: 1989 a. 69; 1991 a. 316; 1999 a. 66; 2015 a. 165.

Sub. (1) (b) does not require proof that the headlights reflected into the eyes of another driver. The statute directs drivers operating within 500 feet to dim their headlights and concludes by describing the purpose of this requirement: to prevent the glaring rays from reflecting into another driver's eyes. An interpretation that would require an ordinary driver using high beams to know whether his or her headlights will impair another driver's vision is absurd. *State v. Tomaszewski*, 2010 WI App 51, 324 Wis. 2d 433, 782 N.W.2d 725, 09-0385.

347.13 Tail lamps and registration plate lamps. (1) No person may operate a motor vehicle, mobile home, or trailer

347.13 EQUIPMENT OF VEHICLES

Updated 23-24 Wis. Stats. 4

or semitrailer upon a highway during hours of darkness or during a period of limited visibility unless the motor vehicle, mobile home, or trailer or semitrailer is equipped with at least one tail lamp mounted on the rear which, when lighted during hours of darkness, emits a red light plainly visible from a distance of 500 feet to the rear. No tail lamp may have any type of decorative covering that restricts the amount of light emitted when the tail lamp is in use. No vehicle originally equipped at the time of manufacture and sale with 2 tail lamps may be operated upon a highway during hours of darkness or during a period of limited visibility unless both lamps are in good working order. This subsection does not apply to any type of decorative covering originally equipped on the vehicle at the time of manufacture and sale.

(2) Every tail lamp on a vehicle shall be located at a height of not more than 72 inches nor less than 20 inches.

(3) No person shall operate on a highway during hours of darkness any motor vehicle upon the rear of which a registration plate is required to be displayed unless such motor vehicle is equipped with a lamp so constructed and placed as to illuminate with a white light the rear registration plate and render it clearly legible from a distance of 50 feet to the rear. Such lamp may be incorporated as part of a tail lamp or may be a separate lamp.

(4) Tail lamps and registration plate lamps shall be so wired as to be lighted whenever the headlamps or auxiliary driving lamps are lighted. In a tractor-semitrailer combination, 2 switches may be employed, one to activate semitrailer lamps and one to activate tractor lamps.

History: 1973 c. 252; 1995 a. 346; 2015 a. 165.

Cross-reference: See also ss. [Trans 305.13](#), [305.16](#), [305.43](#), [305.45](#), and [305.55](#), Wis. adm. code.

A tail lamp is functioning for its intended use and thus in good working order when during hours of darkness it emits a red warning light that is visible to another vehicle traveling 500 feet behind it. Sub.(1) does not require all light bulbs in a tail lamp to be lit. Although s. 347.06 (3) and administrative rules require tail lamps to be kept in "proper working condition," "proper" is not a synonym for "perfect." Rather it is more akin to "good" or "suitable." *State v. Brown*, 2014 WI 69, 355 Wis. 2d 668, 850 N.W.2d 66, 11-2907.

347.14 Stop lamps. (1) No person shall operate a motor vehicle, lightweight utility vehicle as defined in s. [346.94 \(21\) \(a\) 2.](#), mobile home, or trailer or semitrailer upon a highway unless such motor vehicle, lightweight utility vehicle, mobile home, or trailer or semitrailer is equipped with at least one stop lamp mounted on the rear and meeting the specifications set forth in this section. The stop lamp on a mobile home or trailer or semitrailer shall be controlled and operated from the driver's seat of the propelling vehicle. A stop lamp may be incorporated with a tail lamp. No vehicle originally equipped at the time of manufacture and sale with 2 stop lamps shall be operated upon a highway unless both such lamps are in good working order.

(2) A stop lamp shall be so constructed as to be actuated upon application of the service or foot brake or separate trailer brake and shall emit a red or amber light plainly visible and understandable from all distances up to 300 feet to the rear during normal sunlight when viewed from the driver's seat of the vehicle following.

Cross-reference: See also ss. [Trans 305.15](#), [305.43](#), [305.45](#), and [305.55](#), Wis. adm. code.

History: 2009 a. 157.

347.145 Deceleration warning lights for motorcycles, motor bicycles, mopeds or motor buses. (1) A motorcycle, motor bicycle or moped may be equipped with and use a system in which an amber light which pulses in a controlled fashion at a rate which varies exponentially with deceleration is center mounted on the rear of the vehicle.

(2) A motor bus may be equipped with amber lights that shine with a steady beam or that pulse during deceleration, braking, or standing and idling. The lights shall be mounted symmetrically

with respect to the vertical center line of the motor bus in a horizontal alignment on the rear of the motor bus. The lights may be mounted no higher than the lower edge of the rear window, or no higher than 72 inches if the motor bus does not have a rear window.

History: 1981 c. 52; 1983 a. 243; 1987 a. 235; 2001 a. 104.

Cross-reference: See also s. [Trans 305.43](#), Wis. adm. code.

347.15 Direction signal lamps or devices. (1) No person may sell any new motor vehicle, other than a moped or motorcycle, unless such motor vehicle is equipped with direction signal lamps meeting the requirements of this section. No person may operate on a highway any motor vehicle sold new after January 1, 1955, or any mobile home, or trailer or semitrailer sold new after January 1, 1968, other than a vehicle which is operated pursuant to s. [341.47 \(1\) \(b\)](#) or a moped or motorcycle, unless such vehicle is equipped with direction signal lamps meeting the requirements of this section. Any other vehicle may be equipped with such lamps. Subsection (3m) notwithstanding direction signals are not required on trailers when the rear direction signals on the towing vehicle are fully visible from all distances to the rear to 300 feet during normal sunlight when viewed from the driver's seat of the vehicle following.

(2) Except as provided in sub. (1), there shall be at least 2 direction signal lamps showing to the front on motor vehicles and at least 2 showing to the rear on motor vehicles, mobile homes, recreational vehicles, trailers and semitrailers, so as to indicate intention to turn right or left. Lamps showing to the front shall be located on the same level and as widely spaced laterally as practicable and lamps showing to the rear shall be located on the same level and as widely spaced laterally as practicable. Such lamps shall project a flashing white or amber light visible to the front and a flashing red or amber light visible to the rear. Direction signal lamps when in use shall be plainly visible and understandable from all distances to 300 feet during normal sunlight. No direction signal lamp shall have any type of decorative covering that restricts the amount of light emitted when the direction signal lamp is in use. When actuated, such lamps shall indicate the intended direction of turning by flashing the lights showing to the front and rear on the side toward which the turn is made. This subsection does not apply to any type of decorative covering originally equipped on the vehicle at the time of manufacture and sale.

(3) Vehicles equipped with direction signal lamps shall be equipped with a signal visible to the signaling driver when the signaling driver's signal lamps are operating.

(3m) Any motor vehicle or combination of vehicles in use on a highway shall be equipped with direction signals meeting the requirements of this section when the distance from the center of the top of the steering post to the left outside limit of the body, cab or load of such motor vehicle or combination of vehicles exceeds 24 inches, or when the distance from the center of the top of the steering post to the rear limit of the body or load thereof exceeds 14 feet.

(4) Vehicles sold new prior to July 1, 1958, are exempt from the requirements of this section if they either comply with the requirements of s. [85.06 \(15\)](#), 1955 stats., or are exempt from the requirements of that section.

History: 1975 c. 297; 1983 a. 243; 1985 a. 65; 1991 a. 316; 1995 a. 346; 2007 a. 11; 2019 a. 50.

Cross-reference: See also ss. [Trans 305.09](#), [305.43](#), and [305.55](#), Wis. adm. code.

347.16 Clearance lamps and reflectors. (1) No person shall operate on a highway during hours of darkness any vehicle, except automobiles, having a width at any part in excess of 80 inches unless such vehicle is equipped with:

5 Updated 23-24 Wis. Stats.**EQUIPMENT OF VEHICLES****347.23**

(a) Two clearance lamps mounted on the front of the vehicle so as to be visible from the front; and

(b) Two clearance lamps mounted on the rear of the vehicle so as to be visible from the rear; and

(c) Two reflectors mounted on the rear of the vehicle in such a manner as to indicate as nearly as possible the extreme width of the vehicle.

(2) No person shall operate any of the following vehicles on a highway during hours of darkness unless such vehicles are equipped as indicated:

(a) Every truck tractor shall carry on the front 2 clearance lamps, one at each side.

(b) Every trailer or semitrailer shall carry on the rear 2 reflectors, one on each side.

(3) Reflectorized material extending across the full width of the vehicle and otherwise meeting the mounting and visibility specifications for reflectors may be used in lieu of the reflectors required by this section.

Cross-reference: See also ss. [Trans 305.14](#) and [305.55](#), Wis. adm. code.

347.17 Color of clearance and marker lamps and reflectors. Whenever a vehicle is equipped with clearance lamps, sidemarker lamps or reflectors:

(1) Those clearance and marker lamps and reflectors mounted on the front or on the side near the front of the vehicle shall display or reflect an amber color;

(2) Those clearance lamps and marker lamps and reflectors mounted on the rear or on the sides near the rear of the vehicle, or on both, shall display or reflect a red color.

Cross-reference: See also ss. [Trans 305.14](#) and [305.55](#), Wis. adm. code.

347.18 Mounting of clearance lamps and reflectors.

(1) Whenever s. [347.16](#) requires any reflector to be displayed upon a vehicle, each such reflector shall be mounted at a height not less than 16 inches nor more than 60 inches above the ground on which the vehicle stands. On vehicles which are more than 80 inches wide, the front and rear reflectors shall be mounted so as to indicate as nearly as possible the extreme width of the vehicle. Any required red reflector on the rear of a vehicle may be incorporated with the tail lamp but such reflector shall meet all the other reflector requirements of this chapter.

(2) Whenever this chapter requires a vehicle to be equipped with clearance lamps, such lamps shall be mounted in such a manner as to indicate the extreme width of the vehicle and as near to the top thereof as practicable except that when rear identification lamps are mounted at the extreme height of the vehicle, rear clearance lamps may be mounted at optional heights.

History: 1975 c. 121.

Cross-reference: See also ss. [Trans 305.14](#) and [305.55](#), Wis. adm. code.

347.19 Visibility of clearance lamps and reflectors.

(1) Every reflector required by s. [347.16](#) to be displayed upon a vehicle shall be of such size and characteristics and so maintained as to be readily visible during the hours of darkness from all distances within 500 feet to 50 feet from the vehicle when directly in front of lawful upper beams of headlamps.

(2) Front and rear clearance lamps when lighted shall be capable of being seen and distinguished under normal atmospheric conditions during hours of darkness at a distance of 500 feet from the front and rear, respectively, of the vehicle.

Cross-reference: See also ss. [Trans 305.14](#), [305.43](#), and [305.55](#), Wis. adm. code.

347.20 Lamp or flag on projecting load or fixture. (1)

No person shall operate on a highway during hours of darkness any vehicle with a load or fixture thereon extending more than 4 feet beyond the rear of the bed or body thereof unless there is dis-

played at the extreme rear end of the load or fixture a red light or lantern plainly visible from a distance of at least 500 feet to the sides and rear. The red light or lantern shall be in addition to any tail lamp or clearance lamp which the vehicle is required to carry.

(2) No person shall operate on a highway, at times other than hours of darkness, any vehicle with a load or fixture thereon extending more than 4 feet beyond the rear of the bed or body thereof unless there is displayed at the extreme rear end of such load or fixture a red flag or cloth not less than 12 inches square and so hung that the entire area is visible to the operator of a vehicle approaching from the rear.

(3) This section does not apply to vehicles loaded with loose hay or straw.

History: 1981 c. 176.

347.21 Lamps and flags on trains of agricultural vehicles. (1)

No person shall operate on a highway during hours of darkness any train of vehicles authorized by s. [348.08 \(1\) \(d\)](#) unless there is mounted on each side of every vehicle in such train, including farm tractors and implements of husbandry, at least one lamp emitting a red or amber light visible from a distance of 500 feet to the side of the vehicle on which mounted or, in lieu thereof, at least one red or amber reflector visible from all distances within 500 feet to 50 feet of the side of the vehicle when directly in front of lawful upper beams of headlamps.

(1m) No person shall operate on a highway during hours of darkness any train of vehicles authorized by s. [348.08 \(1\) \(b\)](#) unless there is mounted on each side of every vehicle in such train at least one lamp emitting a red or amber light visible from a distance of 500 feet to the side of the vehicle on which mounted or, in lieu thereof, at least one red or amber reflector visible from all distances within 500 feet to 50 feet of the side of the vehicle when directly in front of lawful upper beams of headlamps.

History: 1979 c. 143, 355; 1981 c. 276; 1981 c. 391 s. 210; 1987 a. 164; 2013 a. 377; 2015 a. 232.

347.22 Lamps on farm tractors, self-propelled implements of husbandry, and lightweight utility vehicles.

(1) No person shall operate or park a farm tractor, self-propelled implement of husbandry, or lightweight utility vehicle, as defined in s. [346.94 \(21\) \(a\) 2.](#), upon a highway during hours of darkness unless such tractor, implement of husbandry, or lightweight utility vehicle carries the lighted headlamps and tail lamps which would be required of other motor vehicles under similar circumstances.

(2) Except as provided in s. [347.25 \(2g\)](#), no person shall operate or park a farm tractor, self-propelled implement of husbandry, or lightweight utility vehicle, as defined in s. [346.94 \(21\) \(a\) 2.](#), upon a highway during hours of darkness with any lamp thereon showing any light to the rear other than red or amber in color.

History: 2009 a. 157; 2013 a. 377; 2015 a. 232.

347.23 Lamps on highway maintenance equipment.

(1) No person shall operate upon a highway during hours of darkness any road machinery or motor vehicle used in highway construction or maintenance unless such vehicle or road machinery is equipped either as prescribed by par. (a) or (b):

(a) A red light visible from a distance of 500 feet shall be displayed on each side of the front and on each side of the rear to give adequate warning of the presence of such vehicle or machinery and to show safe clearance for passing or overtaking vehicles; or

(b) In lieu of the red lights prescribed by par. (a), 2 amber floodlamps may be used, one to be mounted on each side of the vehicle or machinery so as to illuminate its sides and its attachments, if any, to show safe clearance for passing or overtaking vehicles. Such floodlamps shall display an amber light of sufficient

347.23 EQUIPMENT OF VEHICLES

Updated 23-24 Wis. Stats. 6

illuminating power to indicate safe clearance from a distance of 200 feet to the front and rear of such vehicle or machinery.

(2) The lights specified in sub. (1) need not be displayed upon motor vehicles used in highway construction or maintenance work when such vehicles are traveling along the highway at their normal operating speed in the ordinary course of traffic.

(4) No person shall operate upon the left-hand side of a highway during hours of darkness any road machinery or motor vehicle used in highway construction or maintenance, including snow and ice control, unless such vehicle or machinery is equipped with an auxiliary lamp or lamps projecting a flashing amber light visible from all directions for a 360-degree lens (beehive type lamp) or revolving type lamp and visible front and rear for reflectorized stationary directional type lamps. For flashing type lamps the number of flashes per minute shall be between 60 and 90. For revolving type lamps the revolutions per minute shall be between 45 and 90. The lenses of such auxiliary lamps shall not be less than 6 inches in diameter for the reflectorized stationary directional type lamp; 3-3/4 inches minimum diameter and 5-inch minimum height for the 360-degree lens (beehive type lamp); and 3-3/4 inches minimum width and 4-5/8 inches minimum height for the revolving type lamp. The lamps shall be equipped with bulbs of 50 candlepower minimum. The lamps shall be mounted approximately midway between the transverse extremities of the vehicle or machinery and at the highest practicable point.

347.24 Lamps and reflectors on nonmotor vehicles and equipment. (1) (a) Except as provided under pars. (b) and (c) and s. 347.22 (1), no person may operate on a highway during hours of darkness any implement of husbandry or any other vehicle not specifically required by law to be equipped with lamps or other lighting devices unless such implement or vehicle is equipped with at least 2 lighted lamps or lanterns exhibiting a white light visible from a distance of 500 feet ahead and 2 lighted lamps or lanterns exhibiting a red light visible from a distance of 500 feet to the rear or, as an alternative to the red lamps or lanterns, 2 red reflectors mounted as specified in s. 347.18 and meeting the visibility requirements of s. 347.19 may be displayed on the rear of such vehicle or implement of husbandry.

(am) No person may operate on a highway during hours of darkness any implement of husbandry that extends 4 feet or more to the left of the center line of its towing vehicle unless the implement is equipped with an amber reflector meeting the visibility requirements of s. 347.19 and mounted on the left side, facing forward, so as to mark the extreme width of the implement to drivers of oncoming vehicles.

(b) Any implement of husbandry or any other vehicle not specifically required by law to be equipped with lamps or other lighting device and which was manufactured on or before January 1, 1984, shall comply with the lamp requirements of s. 347.24 (1), 1981 stats.

(c) An implement of husbandry which is an all-terrain vehicle or utility terrain vehicle need only comply with the lamp requirements established under s. 23.33 (6).

(d) An off-highway motorcycle, as defined in s. 23.335 (1) (q), that is being operated as an implement of husbandry off a highway need only comply with the lamp requirements established under s. 23.335 (17) (a).

(2) No person may operate on a highway during hours of darkness or during periods of inclement weather a vehicle drawn by an animal unless the vehicle is equipped with at least one lighted white light visible from a distance of 500 feet ahead and 2 lighted red lights and 2 yellow or amber strobe lights visible from a distance of 500 feet to the rear. The red rear lights shall be mounted in such a manner as to indicate the extreme width of the

vehicle. The yellow or amber strobe lights shall be mounted not more than 6 inches from the lateral extremities of the vehicle.

(3) (a) In this subsection, “wide implement of husbandry” means any implement of husbandry that has a total width in excess of 15 feet or that partly extends, when operated primarily on the right half of the roadway, over the center of the roadway into any lane intended for travel in the opposite direction.

(b) Except as provided in par. (bm), no person may operate on a highway any wide implement of husbandry unless it is equipped with all of the following and any lamp or light required under this paragraph is lighted and visible at the time of operation:

1. At least 2 amber flashing warning lamps, visible from both the front and rear of the implement of husbandry. When lighted, these lamps shall be capable of being seen and distinguished under normal atmospheric conditions during hours of darkness at a distance of 500 feet from the front and rear of the implement of husbandry. These lamps shall be mounted, as nearly as practicable, to indicate the extreme width of the implement of husbandry, but not more than 16 inches from the lateral extremities of the implement of husbandry.

2. Red retroreflective conspicuity material, visible to the rear and mounted within 25 inches of, respectively, the extreme left and extreme right of the implement of husbandry and spaced as evenly as practicable. This conspicuity material shall be of such size and characteristics and so maintained as to be readily visible during the hours of darkness from all distances within 500 feet to 50 feet from the implement of husbandry when directly in front of lawful upper beams of headlamps.

3. At least 2 strips of yellow retroreflective conspicuity material visible to the front of the implement of husbandry. On the left and right sides of the implement of husbandry, the outer edge of at least one strip of this material shall be mounted within 16 inches of, respectively, the extreme left and extreme right of the implement of husbandry. This conspicuity material shall be of such size and characteristics and so maintained as to be readily visible during the hours of darkness from all distances within 500 feet to 50 feet from the implement of husbandry when directly in front of lawful upper beams of headlamps.

4. Subject to ss. 347.06 (1) and (3), 347.13 (2), and 347.22 (1), at least 2 red tail lamps mounted symmetrically to the rear of the implement of husbandry, or as close to the rear as practicable. These tail lamps are not required to be wired to light when headlamps or other lamps light. When lighted, these tail lamps shall be capable of being seen and distinguished under normal atmospheric conditions during hours of darkness at a distance of 500 feet from the rear of the implement of husbandry.

(bm) A person may operate on a highway, at times other than hours of darkness, a wide implement of husbandry that does not comply with par. (b) if all of the following apply:

1. The wide implement of husbandry is accompanied by an escort vehicle operating with hazard lights activated.

2. Two orange or red flags, not less than 12 inches square, are attached to the rear of the wide implement of husbandry, or as close to the rear as practicable, in a manner that is clearly visible to the operator of a vehicle approaching from the rear and that marks the extreme left and extreme right of the implement of husbandry.

(c) In addition to any applicable requirement under par. (b) or (bm), if a wide implement of husbandry has a total width in excess of 22 feet, no person may operate the implement of husbandry on a highway unless the implement of husbandry is accompanied by an escort vehicle operating with hazard lights activated. If the implement of husbandry is being operated on a highway with only one lane for travel in each direction, the escort vehicle shall be operated ahead of the implement of husbandry on

7 Updated 23-24 Wis. Stats.

EQUIPMENT OF VEHICLES

347.25

the highway. If the implement of husbandry is being operated on a highway with more than one lane for travel in each direction or on a 3-lane highway, the escort vehicle shall be operated behind the implement of husbandry on the highway. This paragraph does not apply to an implement of husbandry that is traveling between fields or between a farm and a field and is operated on the highway for a distance of 0.5 miles or less.

(d) No person may operate on a highway any implement of husbandry manufactured on or after January 1, 2014, unless it is equipped with all lighting and marking devices with which the implement of husbandry was originally equipped by the manufacturer and all such lighting and marking devices are in good working order and visible at the time of operation.

(e) The requirements under this subsection apply in addition to any applicable requirements under subs. (1) and (2) and ss. 347.21, 347.22, and 347.27.

History: 1977 c. 418; 1983 a. 124; 1985 a. 29; 1993 a. 455; 2001 a. 104; 2011 a. 208; 2013 a. 377; 2015 a. 170, 232; 2017 a. 228.

347.245 Identification emblem on certain slow moving vehicles. (1) No person may operate on a highway any vehicle or equipment, any implement of husbandry, any animal-drawn vehicle, or any other machinery, including all road machinery, that usually travels at speeds of less than 25 miles per hour or any vehicle operated under a special restricted operator's license issued under s. 343.135 or any lightweight utility vehicle, as defined in s. 346.94 (21) (a) 2., unless there is displayed on the most practicable visible rear area of the vehicle or combination of vehicles, a slow moving vehicle (SMV) emblem as described in and displayed as provided in sub. (2). Any towed vehicle or machine is exempt from this provision if the towing vehicle is visible from the rear and is in compliance with this section. All road machinery is excluded when it is engaged in actual construction or maintenance work either guarded by a flagman or clearly visible warning signs. The requirement of the emblem shall be in addition to any lighting devices required or permitted by law. Mopeds and motor bicycles are excluded from the provisions of this section unless they are operated under a special restricted operator's license issued under s. 343.135. Electric scooters, electric personal assistive mobility devices, and personal delivery devices are excluded from the provisions of this section. The SMV emblem need not be displayed on vehicles moving directly across the highway.

(2) Standards and specifications for the design and position of mounting of the SMV emblem shall be established by rule by the secretary. The standards and specifications for SMV emblems shall correlate with and, so far as possible, conform with those approved by the American society of agricultural engineers. The secretary shall submit such standards and specifications, and any subsequent changes therein, to the assembly and senate committees having jurisdiction over transportation matters as determined by the speaker of the assembly and the president of the senate acting jointly for their approval.

(3) No person shall display such emblem on a roadway, except as provided in sub. (1), nor on roadside stationary objects such as mailboxes or signposts and no such emblem shall be used as a clearance marker for wide vehicles. No slow moving vehicle actually engaged in construction or maintenance guarded by a flagman or clearly visible warning signs need remove the slow moving vehicle emblem.

(4) No person shall display such emblem on any vehicle or equipment not specified in sub. (1).

(5) This section does not apply to any vehicle or combination of vehicles to the left rear of which is attached a yellow or amber

flashing light at least 4 inches in diameter, except to an implement of husbandry.

History: 1977 c. 29, 288; 1979 c. 34; 1981 c. 138; 1987 a. 164; 2001 a. 90; 2009 a. 157; 2013 a. 377; 2015 a. 232; 2017 a. 13; 2019 a. 11.

Cross-reference: See also ch. Trans 304, Wis. adm. code.

As applied to Amish appellants, requiring slow moving vehicle signs on buggies unconstitutional infringing on religious liberties. *State v. Miller*, 202 Wis. 2d 56, 549 N.W.2d 235 (1996), 94-0159.

347.25 Special warning lamps on vehicles. (1) Except as provided in subs. (1m) (a), (1n), (1r), and (1s), an authorized emergency vehicle may be equipped with one or more flashing, oscillating, or rotating red lights, except that ambulances, fire department equipment, privately owned motor vehicles under s. 340.01 (3) (d), (dg), or (dm) being used by personnel of a full-time or part-time fire department, by members of a volunteer fire department or rescue squad, or by an organ procurement organization or any person under an agreement with an organ procurement organization, and privately owned motor vehicles under s. 340.01 (3) (dh) being used to transport or pick up medical devices or equipment, may be equipped with red or red and white lights, and shall be so equipped when the operator thereof is exercising the privileges granted by s. 346.03 or 346.215 (2) (a). The lights shall be so designed and mounted as to be plainly visible and understandable from a distance of 500 feet both during normal sunlight and during hours of darkness. No operator of an authorized emergency vehicle may use the warning lights except when responding to an emergency call or when in pursuit of an actual or suspected violator of the law, when responding to but not upon returning from a fire alarm, when transporting an organ for human transplantation, when transporting medical personnel for the purpose of performing human organ harvesting or transplantation immediately after the transportation, when necessarily parked in a position which is likely to be hazardous to traffic, or as authorized under s. 346.215 (2) (a).

(1m) (a) A police vehicle under s. 340.01 (3) (a) may be equipped with a blue light and a red light which are flashing, oscillating or rotating.

(b) If the vehicle is so equipped, the lights shall be illuminated as required under s. 346.03 or 346.215 (2) (a) when the operator of the police vehicle is exercising the privileges granted under s. 346.03 or 346.215 (2) (a). On a marked police vehicle with an exterior light bar, the blue light shall be mounted on the roof of the passenger side of the vehicle and the red light shall be mounted on the roof of the driver side of the vehicle. If lights are mounted inside the vehicle, blue lights shall be displayed on the interior of the passenger side of the vehicle and red lights shall be displayed on the interior of the driver side of the vehicle. On marked police vehicles with blue lights displayed on the passenger side roof or interior and red lights displayed on the driver side roof or interior, a combination of additional blue and red lights may be mounted on the front, sides, or rear of a police vehicle in any configuration. When in use on an unmarked police vehicle, the blue light shall be displayed on the passenger side of the vehicle and the red light shall be displayed on the driver side of the vehicle. The lights shall be designed and displayed so as to be plainly visible and understandable from a distance of 500 feet during normal sunlight and during hours of darkness. No operator of a police vehicle may use the warning lights except when responding to an emergency call or when in pursuit of an actual or suspected violator of the law, when responding to but not upon returning from a fire alarm, when necessarily parked on a highway in a position which is likely to be hazardous to traffic using the highway, or as authorized under s. 346.215 (2) (a).

(c) If the state or any local authority intends to equip its police vehicles as authorized under par. (a), the state or the local authority shall give notice of its intent as a class 2 notice under ch. 985 at least 90 days before so equipping the first vehicle.

347.25 EQUIPMENT OF VEHICLES

Updated 23-24 Wis. Stats. 8

(1n) A police vehicle under s. 340.01 (3) (a) may be equipped with one or more flashing white lights. The lights shall be designed and displayed so as to be plainly visible and understandable from a distance of 500 feet both during normal sunlight and during hours of darkness. The lights may be used only when the warning lamps authorized under sub. (1) or (1m) are in use.

(1r) (a) 1. A police vehicle under s. 340.01 (3) (a) may be equipped so that the high beams of its headlamps pulsate or flash alternately at a rate of 70 to 90 pulses or flashes per minute. The pulsating or flashing headlamps may be used only when the warning lamps authorized under sub. (1) or (1m) are in use.

2. If the state or any local authority intends to equip its police vehicles as authorized under subd. 1., the state or the local authority shall give notice of its intent as a class 2 notice under ch. 985 at least 90 days before so equipping the first vehicle.

(b) 1. a. A vehicle of a fire department under s. 340.01 (3) (c) or an ambulance under s. 340.01 (3) (g) may be equipped so that the high beams of its headlamps pulsate or flash alternately at a rate of 70 to 90 pulses or flashes per minute. The pulsating or flashing headlamps may be used only when the warning lamps authorized under sub. (1) are in use.

b. If any local authority intends to equip its vehicles as authorized under subd. 1. a., the local authority shall give notice of its intent as a class 2 notice under ch. 985 at least 90 days before so equipping the first vehicle.

2. a. A sheriff or others designated by the county board may authorize that an ambulance under s. 340.01 (3) (i) be equipped so that the high beams of its headlamps pulsate or flash alternately at a rate of 70 to 90 pulses or flashes per minute. The pulsating or flashing headlamps may be used only when the warning lamps authorized under sub. (1) are in use.

b. If the sheriff or others designated by the county board intend to authorize any ambulance under s. 340.01 (3) (i) to be equipped as authorized under subd. 2. a., the local authority shall give notice of its intent as a class 2 notice under ch. 985 at least 90 days before authorizing the first vehicle to be so equipped.

(c) 1. a. The state fire marshal may authorize that a privately owned motor vehicle under s. 340.01 (3) (d) that is being used by a deputy state fire marshal be equipped so that the high beams of its headlamps pulsate or flash alternately at a rate of 70 to 90 pulses or flashes per minute. The pulsating or flashing headlamps may be used only when the warning lamps authorized under sub. (1) are in use.

b. If the state fire marshal intends to authorize any privately owned motor vehicle under s. 340.01 (3) (d) that is being used by a deputy state fire marshal to be equipped as authorized under subd. 1. a., the state shall give notice of its intent as a class 2 notice under ch. 985 at least 90 days before authorizing the first vehicle to be so equipped.

2. a. A fire chief may authorize that a privately owned motor vehicle under s. 340.01 (3) (d) that is being used by an employee of the fire department or, if applicable, a member of the volunteer fire department be equipped so that the high beams of its headlamps pulsate or flash alternately at a rate of 70 to 90 pulses or flashes per minute. The pulsating or flashing headlamps may be used only when the warning lamps authorized under sub. (1) are in use.

b. If the fire chief intends to authorize any privately owned motor vehicle under s. 340.01 (3) (d) that is being used by an employee of the fire department or, if applicable, a member of the volunteer fire department to be equipped as authorized under subd. 2. a., the local authority shall give notice of its intent as a class 2 notice under ch. 985 at least 90 days before authorizing the first vehicle to be so equipped.

(1s) A vehicle in use by a fire department as a command post

at the site of an emergency call may be equipped with a blue or green light which is flashing, oscillating or rotating.

(2) No person may operate a school bus which is painted as provided in s. 347.44 unless it is equipped with a 360-degree flashing white strobe light having a flashrate of 60 to 120 per minute and either flashing red warning lights or flashing red and amber warning lights. The secretary shall prescribe rules for the type, installation, operation and light output brilliance of the lights required under this subsection. No vehicle may be equipped with the warning and strobe lights required under this subsection unless it also is painted as provided in s. 347.44.

Cross-reference: See also ch. Trans 300, Wis. adm. code.

(2g) No person may operate on a highway any self-propelled implement of husbandry having a total width in excess of 12 feet unless it is equipped with a 360-degree yellow or amber rotating strobe or beacon light, mounted at the highest practicable point, or 2 flashing amber lights visible to the front and rear, and the light or lights are activated.

(2m) A human service vehicle may be equipped with a 360-degree flashing strobe light with a flashrate of 60 to 120 per minute. Notwithstanding s. 110.05 (1), the secretary shall prescribe rules for the type, color, installation, operation and light output brilliance of the lights permitted under this subsection.

(3) The lead vehicle in a funeral procession may be equipped, or any vehicle in the procession may be equipped if all vehicles in the procession are so equipped, with a flashing amber or purple light that may be used only in the procession.

(4) No vehicle may be equipped with or display any blue colored light or lamp unless the vehicle is used in police work authorized by the state or a political subdivision of the state or is used by a fire department as authorized under sub. (1s).

(5) Notwithstanding s. 347.26 (11), whenever flashing warning lamps on an authorized emergency vehicle are designed and being used to exhibit a directional arrow at the scene of an emergency, the lamps exhibiting the directional arrow may be flashing simultaneously or sequentially. If the use of flashing warning lamps to exhibit a directional arrow would likely direct approaching traffic into a lane of traffic moving in the opposite direction, only the flashing warning lamps that exhibit the horizontal bar of a directional arrow may be used and such lamps shall be flashing simultaneously.

History: 1977 c. 29 s. 1654 (7) (c); 1977 c. 228; 1979 c. 54, 149; 1983 a. 56; 1985 a. 143; 1987 a. 126; 1989 a. 69; 1991 a. 73, 142; 1993 a. 369; 1995 a. 31, 190; 1997 a. 31, 117; 2007 a. 20, 177; 2009 a. 46; 2013 a. 95, 96, 313, 377; 2015 a. 232; 2025 a. 39, 52.

The trial court acted erroneously in imposing the burden of proof as to the intensity of the light upon the plaintiff. The statutory exemption of emergency vehicles from adherence to traffic regulations is available as an affirmative defense, and the defendants bear the burden of proving the necessary compliance with the statutory condition. A light showing only to the front would not provide the operator with emergency privileges for stopping, parking, or turning as to vehicles approaching from the rear. *Pittman v. Liefkring*, 59 Wis. 2d 52, 207 N.W.2d 610 (1973).

347.26 Restrictions on certain optional lighting equipment. (1) GENERAL RESTRICTIONS.

A vehicle need not be equipped with the lamps specified in this section, but if a vehicle is equipped with any such lamps, no person shall operate such vehicle on a highway during hours of darkness unless such lamps comply with the requirements of this section and no person shall use such lamps in a manner inconsistent with this section.

(2) SPOTLAMPS. (a) Any motor vehicle may be equipped with not more than 2 spotlamps.

(b) No spotlamp shall be used as a substitute for headlamps. No spotlamp shall be used as an auxiliary driving light on any motor vehicle except when such spotlamp is set or adjusted so that the rays of light are projected directly upon the road surface at a distance not exceeding 150 feet directly in front of the vehicle and to the right of the center of the traveled roadway. No spot-

9 Updated 23-24 Wis. Stats.**EQUIPMENT OF VEHICLES****347.26**

lamp shall project any glaring light into the eyes of an approaching driver.

(3) ADVERSE WEATHER LAMPS. (a) Any motor vehicle may be equipped with not more than 2 adverse weather lamps which shall be mounted on the front of the vehicle below the level of the centers of the headlamps.

(b) Adverse weather lamps shall not be used in lieu of headlamps unless absolutely necessary in case of rain, snow, dust or fog and then only when a vehicle is equipped with 2 adverse weather lamps mounted on opposite sides of the front of the vehicle and when both such adverse weather lamps are lighted. Whenever any vehicle is equipped with only one adverse weather lamp, both headlamps of such vehicle shall be lighted at all times when such adverse weather lamp is lighted.

(4) BACK-UP LAMPS. (a) Except as provided in par. (am), any motor vehicle may be equipped with not more than 2 back-up lamps which shall be so directed as to project a white or amber light illuminating the roadway to the rear of such vehicle for a distance not to exceed 75 feet.

(am) In addition to the lamps authorized under par. (a), a school bus that is painted as provided in s. 347.44 (1) may be equipped with one amber or white back-up lamp on each side. The lamps shall be mounted no more than 20 inches behind or 20 inches in front of the wheel housing area and below the floor line rub rail. The illumination shall be directed down and back for a distance not to exceed 75 feet. The secretary may prescribe rules for the specifications, installation, and operation of lamps authorized under this paragraph.

(b) No lighted back-up lamp shall be displayed on any vehicle upon a highway except when such vehicle is about to be or is being driven backward. Whenever a back-up lamp is lighted during hours of darkness, the tail lamp or tail lamps on the vehicle displaying such lighted back-up lamp also shall be lighted.

(5) IDENTIFICATION LAMPS ON TAXICABS AND BUSES. (a) No person shall operate a motor vehicle regularly used for transporting passengers for hire displaying any lighting device for identification purposes other than a single illuminated sign or lighted lamp mounted above the top line of the windshield, colored white, amber or green. Such illuminated sign or lamp shall be so constructed as to emit a steady or flashing nonglaring light.

(b) A school bus that is painted as provided in s. 347.44 (1) may be equipped with one illuminated sign mounted on the front above the windshield and one illuminated sign mounted on the rear above the window. The illuminated signs authorized under this paragraph shall emit a steady, nonglaring light.

(6) WARNING LAMPS ON TOW TRUCKS AND SERVICE VEHICLES. (a) Any vehicle which by reason of its use upon a highway creates a vehicular traffic hazard requiring the exercise of unusual care in approaching, overtaking or passing shall be equipped with a flashing or rotating amber lamp of the dome type at the highest practicable point, visible from a distance of 500 feet, or 2 flashing amber lamps, one showing to the front and one showing to the rear, visible from a distance of 500 feet and mounted approximately midway between the extremities of the width of the vehicle and at the highest practicable point. Such amber lamp or lamps shall be lighted when such vehicle is moving a disabled vehicle along or upon a public highway at a speed below the average speed of motor vehicle traffic on such street or highway and may not be lit at other times.

(b) Operators of tow trucks or towing vehicles shall equip each tow truck or towing vehicle with a flashing or rotating red lamp, in addition to flashing type amber lamps. Such lamp shall be placed on the dome of the vehicle at the highest practicable point visible from a distance of 500 feet. This flashing red lamp shall be used only when such vehicle is standing on or near the

traveled portion of a highway preparatory to towing or servicing the disabled vehicle.

(7) WARNING LAMPS ON CERTAIN HIGHWAY VEHICLES. Any vehicle of the department or a county or municipal highway department that by reason of its use upon a highway creates a vehicular traffic hazard requiring the exercise of unusual care in approaching, overtaking, or passing may be equipped with any of the following configurations of flashing red, amber, or green lamps:

(a) A lamp of the dome-light type.

(b) Two lamps, one showing to the front and one showing to the rear. The lamps shall be mounted approximately midway between the extremities of the width of the vehicle and at the highest practicable point and shall be used only for the purpose of warning operators of other vehicles of the presence of the traffic hazard.

(c) Four lamps, 2 showing to the front and 2 showing to the rear. The lamps showing to the front shall be mounted at the same level and as widely spaced laterally as practicable. The lamps showing to the rear shall be mounted at the same level and as widely spaced laterally as practicable.

(8) WARNING LAMPS FOR MAIL DELIVERY VEHICLES. Any vehicle used for mail delivery may be equipped with a flashing amber lamp or strobe light mounted at the highest practicable point and showing to the front and rear that may be used only to warn other motorists of the presence of a vehicular traffic hazard requiring the exercise of unusual care in approaching, overtaking or passing when the vehicle is being used to deliver mail.

(9) WARNING LAMPS ON PUBLIC UTILITY AND COOPERATIVE VEHICLES. (a) Subject to par. (b), any vehicle of a public utility, as defined in s. 196.01 (5), telecommunications carrier, as defined in s. 196.01 (8m), or cooperative association organized under ch. 185 for the purpose of producing or furnishing heat, light, power, or water to its members that by reason of its use upon a highway creates a vehicular traffic hazard requiring the exercise of unusual care in approaching, overtaking, or passing may be equipped with any of the following configurations of flashing amber or green lamps:

1. A lamp of the dome-light type.

2. Two lamps, one showing to the front and one showing to the rear. The lamps shall be mounted approximately midway between the extremities of the width of the vehicle and at the highest practicable point and shall be used only for the purpose of warning operators of other vehicles of the presence of the traffic hazard. If the mounting of lamps midway between the extremities of the width of the vehicle is impracticable because of the vehicle's design, then the mountings shall be made at or near the upper left front and rear corners of the vehicle.

3. Four lamps, 2 showing to the front and 2 showing to the rear. The lamps showing to the front shall be mounted at the same level and as widely spaced laterally as practicable. The lamps showing to the rear shall be mounted at the same level and as widely spaced laterally as practicable.

(b) In this paragraph, "maintenance and restoration of utility service" means the immediate restoration of a utility service that is outside the normal parameters of general maintenance or construction when damage or interruption of service has been caused to utility infrastructure by adverse weather or other events and that requires utility crews to park utility vehicles in the roadway or on the shoulder of the roadway. No person may use flashing green lamps under par. (a) unless the vehicle upon which the lamps are mounted is operated for the purpose of maintenance and restoration of utility service.

(10) FLASHING AMBER LIGHT ON OVERSIZE VEHICLE. Any vehicle moving on the highway pursuant to an oversize permit is-

347.26 EQUIPMENT OF VEHICLES

Updated 23-24 Wis. Stats. 10

sued under s. 348.25, 348.26 or 348.27 may be equipped with a flashing amber dome light upon the cab of such vehicle or with double faced flashing amber light mounted along the sides of such vehicle mounted and used when the movement is oversize.

(11) FLASHING WARNING LAMPS. (a) Any vehicle may be equipped with lamps which may be used for the purpose of warning the operators of other vehicles of the presence of a vehicular traffic hazard requiring the exercise of unusual care in approaching, overtaking or passing, and when so equipped may display such warning in addition to any other warning signals required by this section. The lamps used to display such warning to the front shall be mounted at the same level and as widely spaced laterally as practicable, and shall display simultaneously flashing white or amber lights, or any shade of color between white and amber. The lamps used to display such warning to the rear shall be mounted at the same level and as widely spaced laterally as practicable, and shall show simultaneously flashing amber or red lights, or any shade of color between amber and red. These warning lights shall be visible from a distance of not less than 500 feet under normal atmospheric conditions at night. Directional signals meeting the requirements of this chapter shall be used or lamps meeting these requirements, mounted so as to comply with turn signal installation.

(am) In addition to any other lamps authorized under this subsection, a motor truck having a gross vehicle weight rating of more than 26,000 pounds may be equipped with a 360-degree flashing or rotating amber light mounted at the highest practicable point. The flashing or rotating amber lamp may be lighted only when the motor truck is upon a highway having a maximum speed limit of more than 35 miles per hour and the motor truck is traveling 10 or more miles per hour below the maximum speed limit, is stopped, or is backing on such highway. The flashing or rotating amber lamp may not be lit at other times.

(b) Whenever any vehicle other than an automobile, which is equipped as permitted in par. (a), is stopped for more than 10 minutes on the traveled portion of any highway, or shoulder thereof, during hours of darkness, the driver of such vehicle shall display warning signals as required by s. 347.29.

History: 1977 c. 29 s. 1654 (8) (a); 1983 a. 53 s. 114; 1985 a. 204; 1989 a. 134, 336; 1993 a. 496; 2005 a. 38; 2021 a. 255; 2023 a. 155; 2025 a. 208.

Cross-reference: See also ss. Trans 305.075, 305.08, 305.10, and 305.11, Wis. adm. code.

347.27 When lighted lamps required on parked vehicles. (1) No person shall park or leave a vehicle standing, whether attended or unattended, upon a roadway or the shoulder immediately adjacent thereto during hours of darkness unless:

(a) Such vehicle is parked or standing where there is sufficient artificial light to render it visible from a distance of 500 feet or is lawfully parked within the corporate limits of a city or village and in either case is equipped with at least one red reflector mounted on the rear thereof as near as practicable to the side of the vehicle which is closest to passing traffic and otherwise meeting the mounting and visibility requirements specified in ss. 347.18 and 347.19; or

(b) Such vehicle displays one or more lighted lamps meeting the following requirements:

1. At least one lamp shall display a white or amber light visible from a distance of 500 feet to the front of the vehicle, and the same lamp or at least one other lamp shall display a red light visible from a distance of 500 feet to the rear of the vehicle.

2. The location of such lamp or lamps shall always be such that at least one lamp or combination of lamps meeting the requirements of this section is installed as near as practicable to the side of the vehicle which is closest to passing traffic.

3. If the vehicle is equipped with 2 parking lamps and 2 tail lamps, both parking lamps and both tail lamps shall be lighted.

(2) Any lighted headlamps on a vehicle parked on a highway shall be depressed or dimmed.

(3) In this section, "vehicle" includes farm tractors, implements of husbandry, animal-drawn vehicles, lightweight utility vehicles as defined in s. 346.94 (21) (a) 2., and road machinery.

History: 2009 a. 157; 2015 a. 232.

347.28 Certain vehicles to carry flares or other warning devices. (1) No person shall operate a motor truck or motor bus more than 80 inches in width or a truck tractor or road tractor on any highway outside the corporate limits of a city or village during hours of darkness unless such vehicle carries in a place readily accessible to the driver the following warning devices:

(a) At least 3 pot torches or 3 red electric lanterns or 3 red emergency reflectors, each of which shall be capable of being seen and distinguished at a distance of at least 600 feet under normal atmospheric conditions during hours of darkness. If pot torches are carried in lieu of red electric lanterns, at least 3 red-burning fusees shall be carried in addition to such pot torches; and

(b) At least 2 red-cloth flags, not less than 12 inches square, with standards to support such flags.

(2) No person shall operate upon a highway outside the corporate limits of a city or village during hours of darkness any motor vehicle used for the transportation of explosives or any cargo tank truck used for the transportation of flammable liquids or compressed gases unless there is carried in such vehicle 3 red electric lanterns or 3 red emergency reflectors meeting the requirements of sub. (1). No pot torch or fusee or signal produced by flame shall be carried in any such vehicle. Such red emergency reflectors shall comply with the specifications for such reflectors as set forth in interstate commerce commission motor carrier safety regulations.

347.29 Display of warning devices for certain vehicles when standing on highway. (1) Except as provided in s. 347.26 (11) (b), whenever any motor truck, motor bus, trailer or semitrailer more than 80 inches in width or truck tractor or road tractor is left standing, whether attended or unattended, during hours of darkness upon the traveled portion of any highway or the shoulder adjacent thereto outside the corporate limits of a city or village, the operator of such vehicle shall display the following warning devices upon the highway during the entire time the vehicle is so left standing and such devices shall be placed in the following order:

(a) A lighted fusee or lighted red electric lantern or a red emergency reflector shall immediately be placed at the traffic side of the vehicle in the direction of the nearest approaching traffic. If a lighted fusee was so placed, the driver shall replace such fusee with a lighted pot torch or lighted red electric lantern or a red emergency reflector after the driver has placed the warning devices specified in pars. (b) and (c) and before the fusee burns out.

(b) A lighted pot torch or lighted red electric lantern or a red emergency reflector shall be placed approximately 100 feet from the standing vehicle in the center of the lane occupied by such vehicle and toward traffic approaching in that lane.

(c) One lighted pot torch or lighted red electric lantern or a red emergency reflector shall be placed approximately 100 feet from the standing vehicle in the center of the lane occupied by such vehicle and in the opposite direction from the warning device placed in accordance with par. (b).

(2) Whenever any vehicle referred to in this section is left

11 Updated 23-24 Wis. Stats.**EQUIPMENT OF VEHICLES****347.35**

standing, whether attended or unattended, within 500 feet of a curve, hillcrest or other obstruction to view, the warning signal in that direction shall be so placed as to afford ample warning to other users of the highway, but in no case less than 100 feet nor more than 500 feet from the standing vehicle.

(3) Whenever any vehicle of a type referred to in this section is left standing, whether attended or unattended, upon any roadway of a divided highway during hours of darkness, the appropriate warning devices prescribed in subs. (1) and (4) shall be placed as follows:

(a) One shall be placed at a distance of approximately 200 feet from the vehicle in the center of the lane occupied by the standing vehicle and in the direction of traffic approaching in that lane;

(b) One shall be placed at a distance of approximately 100 feet from the vehicle in the center of the lane occupied by the vehicle and in the direction of traffic approaching in that lane;

(c) One shall be placed at the traffic side of the vehicle and approximately 10 feet from the vehicle in the direction of the nearest approaching traffic.

(4) No operator of a motor vehicle used in the transportation of explosives, or of a cargo tank truck used for the transportation of any flammable liquid or compressed flammable gas shall use any flame-producing emergency signal for protecting any such vehicle. In lieu thereof, red electric lanterns or red emergency reflectors shall be used, the placement of which shall be in the same order and manner as prescribed in subs. (1) to (3).

(5) Whenever any vehicle of a type referred to in this section is left standing at any place mentioned in this section at times other than during hours of darkness, the operator of the vehicle shall display 2 red flags upon the roadway in the lane of traffic occupied by the standing vehicle, one at a distance of approximately 100 feet in advance of the vehicle and one at a distance of approximately 100 feet to the rear of the vehicle.

(6) The flares, fusees, red electric lanterns, red emergency reflectors and flags to be displayed as required in this section shall conform with the requirements of s. 347.28.

(7) This section does not apply to vehicles standing on a highway in compliance with traffic regulations or the directions of a traffic officer or official traffic sign or signal.

History: 1991 a. 316.

A flag warning under sub. (5) is not applicable in a city. *Northland Insurance Co. v. Avis Rent-A-Car*, 62 Wis. 2d 643, 215 N.W.2d 439 (1974).

347.30 Penalty for violating lighting equipment requirements. (1) Any person violating s. 347.06 or 347.13 (2), (3) or (4) may be required to forfeit not less than \$10 nor more than \$20 for the first offense and not less than \$25 nor more than \$50 for the 2nd or subsequent conviction within a year.

(2) Any person violating ss. 347.03, 347.07 to 347.12, 347.13 (1) or 347.14 to 347.29 may be required to forfeit not less than \$10 nor more than \$200.

(3) Notwithstanding sub. (2), on or after April 5, 2018, and before 6 months after April 5, 2018, if a person violates s. 347.24 (2) by operating on a highway during hours of darkness a vehicle that is drawn by an animal and that is not equipped with 2 yellow or amber strobe lights visible from a distance of 500 feet to the rear and mounted not more than 6 inches from the lateral extremities of the vehicle, a law enforcement officer shall issue the person a warning notice and may not issue a citation.

History: 1971 c. 278; 2017 a. 228.

SUBCHAPTER III

OTHER EQUIPMENT

347.35 Brakes. (1) **MOTOR VEHICLES.** No person shall operate any motor vehicle, other than a moped or motorcycle, upon a highway unless such motor vehicle is equipped with brakes adequate to control the movement of and to stop and hold such vehicle and capable of meeting the performance specifications under s. 347.36. There shall be 2 separate means of applying the brakes, each of which means shall be effective to apply the brakes to at least 2 wheels.

(1a) **PARKING BRAKES.** Every such vehicle and combination of vehicles, except mopeds and motorcycles, shall be equipped with parking brakes adequate to hold the vehicle on any grade on which it is operated, under all conditions of loading on a surface free from snow, ice or loose material. The parking brakes shall be capable of being applied by the driver's muscular effort or by spring action or by equivalent means. Their operation may be assisted by the service brakes or other source of power provided that failure of the service brake actuation system or other power assisting mechanism will not prevent the parking brakes from being applied. The parking brakes shall be so designed that when once applied they shall remain applied with the required effectiveness despite exhaustion of any source of energy or leakage of any kind. The same brake drums, brake shoes and lining assemblies, brake shoe anchors and mechanical brake shoe actuation mechanism normally associated with the wheel brake assemblies may be used for both the service brakes and the parking brakes. If the means of applying the parking brakes and the service brakes are connected in any way, they shall be so constructed that failure of any one part shall not leave the vehicle without operative brakes.

(2) **MOPEDS AND MOTORCYCLES.** No person may operate a moped or motorcycle upon a highway unless the moped or motorcycle is equipped with at least one brake capable of meeting the performance specifications set forth in s. 347.36. The brake may be designed to be operated either by hand or by foot.

(3) **TRAILERS, SEMITRAILERS AND TOWED VEHICLES.** (a) Except as provided in par. (am), no person shall operate on a highway any trailer, semitrailer or other towed vehicle having a gross weight of 3,000 pounds or more and manufactured after January 1, 1942 unless such vehicle is equipped with brakes adequate to control the movement of and to stop and hold it.

(am) A motor vehicle may be towed without being equipped with brakes as provided in par. (a) if the gross weight of the towed vehicle is not more than 40 percent of the gross weight of the towing vehicle and the brakes on the towing vehicle are capable of bringing the combination of towing vehicle and towed vehicle to a stop as provided in s. 347.36 (1).

(b) Every full trailer, semitrailer, pole trailer or other towed vehicle required to be equipped with brakes shall be equipped with brake systems of such design and type, and capable of meeting such performance standards, as established by rule of the department.

(c) This subsection does not apply to farm trailers or to disabled vehicles while being towed to a place of repair or to automobiles or trucks while being towed or being transported pursuant to s. 341.47 (1) (b).

(4) **MOBILE HOMES AND RECREATIONAL VEHICLES.** No person shall manufacture and no person shall sell a mobile home or recreational vehicle in this state unless such mobile home or recreational vehicle is equipped with brakes adequate to control the movement of and to stop and hold it. No person shall operate on a highway any mobile home registered as a 1940 or later year model or recreational vehicle unless such mobile home or recreational vehicle is equipped with brakes adequate to control the movement of and to stop and hold it.

(5) **IMPLEMENTS OF HUSBANDRY.** (a) No person may operate

347.35 EQUIPMENT OF VEHICLES

Updated 23-24 Wis. Stats. 12

on a highway any self-propelled implement of husbandry manufactured after February 1, 1985, unless the vehicle is equipped with brakes or other stopping device adequate to control the movement of and to stop and hold the implement of husbandry.

(b) Every self-propelled implement of husbandry required to be equipped with brakes or other stopping device shall be equipped with brakes or a stopping device that meets design, type or performance standards established by the department by rule. The rule of the department under this paragraph shall comply with the applicable standard established by the American society of agricultural engineers.

History: 1977 c. 29 s. 1654 (7) (e); 1979 c. 163; 1983 a. 124, 243, 244; 1985 a. 65; 2007 a. 11; 2019 a. 50.

Cross-reference: See also ch. [Trans 308](#) and ss. [Trans 305.17](#), [305.37](#), and [305.51](#), Wis. adm. code.

347.36 Performance ability of brakes. (1) Brakes on motor vehicles and brakes on combinations of vehicles shall be capable of bringing the vehicle or combination of vehicles to a stop, under normal conditions, within 50 feet when traveling at a speed of 20 miles per hour.

(3) All required brakes shall be maintained in good working order.

History: 1983 a. 243.

Cross-reference: See also ss. [Trans 305.17](#) and [305.37](#), Wis. adm. code.

347.37 Brake fluid, sale regulation. (1) After January 1, 1960, no hydraulic brake fluid for use in motor vehicles shall be sold in this state if such brake fluid is below the minimum standard of specifications established by the society of automotive engineers for heavy duty type brake fluid No. 70R1 or a later designator for an improved product.

(2) All manufacturers of brake fluids selling such fluids in Wisconsin shall state on the immediate containers in which such fluid is packaged that the fluid therein meets or exceeds the specifications under sub. (1).

347.38 Horns and warning devices. (1) No person shall operate a motor vehicle upon a highway unless such motor vehicle is equipped with a horn in good working order and capable of emitting sound audible under normal conditions from a distance of not less than 200 feet, but no person shall at any time use a horn otherwise than as a reasonable warning or make any unnecessary or unreasonably loud or harsh sound by means of a horn or other warning device.

(2) Except as otherwise provided in this section, no vehicle shall be equipped with nor shall any person use upon a vehicle any siren or compression or exhaust whistle.

(3) Any vehicle may be equipped with a theft alarm signal device if such device is so arranged that it cannot be used by the driver as an ordinary warning signal.

(4) An authorized emergency vehicle shall be equipped with a siren, but such siren shall not be used except when such vehicle is operated in response to an emergency call or in the immediate pursuit of an actual or suspected violator of the law, when responding to but not upon returning from a fire alarm, when transporting an organ for human transplantation, or when transporting medical personnel for the purpose of performing human organ harvesting or transplantation immediately after the transportation, in which events the driver of such vehicle shall sound the siren when reasonably necessary to warn pedestrians and other drivers.

Cross-reference: See also ss. [Trans 305.25](#) and [305.41](#), Wis. adm. code.

History: 2007 a. 20.

347.385 Traffic control signal preemption and priority devices. (1m) In this section:

(a) "Authorized emergency vehicle" means an authorized emergency vehicle as defined in s. [340.01 \(3\) \(a\)](#), [\(c\)](#), [\(g\)](#), or [\(i\)](#).

(d) "Political subdivision" means a county, city, village, or town.

(e) "Snow removal vehicle" means any vehicle equipped with a snowplow or anti-icing equipment that is used by a political subdivision for snow removal and is operated by a political subdivision or the agent or lessee of a political subdivision.

(f) "Traffic control signal preemption device" means a device, located on or within a traffic control signal, that is designed to receive an electronic, radio, light, or sound transmission from an approaching vehicle that alters the normal sequence of the traffic control signal to provide or maintain a green signal for the vehicle to proceed through the intersection.

(g) "Traffic control signal priority device" means a device, located on or within a traffic control signal, that is designed to receive an electronic, radio, light, or sound transmission from an approaching vehicle to request that a green signal be provided or maintained for the vehicle to proceed through the intersection.

(i) "Transmitter" means a device that emits a signal for the purpose of activating a traffic control signal preemption device or a traffic control signal priority device.

(2m) An authorized emergency vehicle may be equipped and operated with lamps designed and used, or with any other transmitter designed and used, to activate traffic control signal preemption devices.

(2r) A snow removal vehicle equipped with oscillating, rotating, or flashing lights that is actively engaged in snow removal activities may be equipped and operated with lamps designed and used, or with any other transmitter designed and used, to activate traffic control signal priority devices.

(3m) The lamps authorized for use under this section may be any color and may be flashing, oscillating, rotating or pulsating.

(4) No operator of an authorized emergency vehicle may use a transmitter, including lamps under sub. (2m), except when responding to an emergency call, when pursuing an actual or suspected violator of the law, or when responding to, but not when returning from, a fire alarm.

(5) (a) No person may operate upon a highway a motor vehicle, other than an authorized emergency vehicle or snow removal vehicle, that is equipped with a transmitter or in which a transmitter is located. This subsection does not apply to a motor carrier or person in the business of selling transmitters to authorized users who transports a transmitter in original, unopened packaging or in an inoperative condition in an enclosed storage compartment of the vehicle.

(b) No person may sell a transmitter except for use for authorized purposes as described in sub. (2m) or (2r).

(6) The authority responsible for maintenance of a traffic control signal may establish procedures for resolving conflicts between multiple requests for signal preemption or priority at a traffic signal, except that a signal preemption request from an authorized emergency vehicle must be given priority over any signal priority request.

History: 2005 a. 193 ss. 1 to 6; Stats. 2005 s. 347.385; 2023 a. 167.

347.39 Mufflers. (1) No person shall operate on a highway any motor vehicle subject to registration unless such motor vehicle is equipped with an adequate muffler in constant operation and properly maintained to prevent any excessive or unusual noise or annoying smoke. This subsection also applies to motor bicycles.

(2) No muffler or exhaust system on any vehicle mentioned in sub. (1) shall be equipped with a cutout, bypass or similar device nor shall there be installed in the exhaust system of any such vehi-

13 Updated 23-24 Wis. Stats.**EQUIPMENT OF VEHICLES 347.417**

cle any device to ignite exhaust gases so as to produce flame within or without the exhaust system. No person shall modify the exhaust system of any such motor vehicle in a manner which will amplify or increase the noise emitted by the motor of such vehicle above that emitted by the muffler originally installed on the vehicle, and such original muffler shall comply with all the requirements of this section.

(3) In this section, “muffler” means a device consisting of a series of chambers of baffle plates or other mechanical design for receiving exhaust gases from an internal combustion engine and which is effective in reducing noise.

History: 1983 a. 243.

Cross-reference: See also ss. [Trans 305.20](#) and [305.39](#), Wis. adm. code.

347.40 Mirrors. (1) No person shall operate any motor vehicle upon a highway unless such vehicle is equipped with a mirror so located as to reflect to the operator a view of the roadway for a distance of 200 feet to the rear of such vehicle.

(2) No person shall operate on a highway any school bus having a passenger-carrying capacity of 10 or more persons including the operator unless such bus is equipped with at least one mirror which is 7 inches in diameter so located as to enable the operator to see a reflection of the road from the entire front bumper forward to a point where direct observation is possible.

(3) No person may operate or permit the operation of any motor bus on a highway unless the bus is equipped with 2 outside rearview mirrors, one to the right and one to the left of the operator. Each mirror shall have not less than 50 square inches of unobstructed reflective surface and shall be firmly supported and adjustable to give the operator a clear view past both the right and left rear of the bus.

(4) Notwithstanding sub. (1) and [49 CFR 393.80 \(a\)](#), a commercial motor vehicle, as defined in [49 CFR 390.5](#), may be equipped with a camera monitor system that is exempted from the requirements of [49 CFR 393.80 \(a\)](#) by the federal motor carrier safety administration or approved for use under [49 CFR 393.80](#) or in federal motor vehicle safety standards as an alternative to mirrors. In this subsection, “commercial motor vehicle” includes a commercial motor vehicle operated in intrastate commerce.

History: 1975 c. 84; 1987 a. 235; 2025 a. 51.

Cross-reference: See also ss. [Trans 305.26](#) and [305.44](#), Wis. adm. code.

347.41 Speed indicators. No person shall operate on a highway any motor vehicle primarily designed for use upon a highway unless such motor vehicle is equipped with a speedometer which with reasonable accuracy registers the speed of the vehicle, except that motor trucks or truck tractors may be equipped with tachometers or any other devices that indicate speed and motor vehicles transported pursuant and in compliance with s. [341.47 \(1\) \(b\)](#) and [\(c\)](#) may be equipped with a governor of speed of a type which restricts speed and which is set at a level equal to or below the limits of 55 miles per hour in lieu of a speedometer.

History: 1983 a. 54.

Cross-reference: See also s. [Trans 305.18](#), Wis. adm. code.

347.413 Ignition interlock device tampering; failure to install. (1) No person may remove, disconnect, tamper with, or otherwise circumvent the operation of an ignition interlock device installed in response to the court order under s. [346.65 \(6\)](#), 1999 stats., or s. [343.301 \(1\)](#), 2007 stats., or s. [343.301 \(1g\)](#), or fail to have the ignition interlock device installed as ordered by the court, or violate a court order under s. [343.301 \(1g\)](#) restricting the person’s operating privilege. This subsection does not apply to the removal of an ignition interlock device upon the expiration of the order requiring the motor vehicle to be so equipped or to necessary repairs to a malfunctioning ignition interlock device by a person authorized by the department.

(3) The department shall design a warning label which shall be affixed to each ignition interlock device upon installation. The label shall provide notice of the penalties for tampering with or circumventing the operation of the ignition interlock device under sub. (1) and s. [343.10 \(5\) \(a\) 3](#).

NOTE: This section is renumbered to s. [343.302](#) and amended by [2025 Wis. Act 210](#) eff. on the first day of the 12th month beginning after the date specified in the Department of Transportation notice published in the Wisconsin Administrative Register under [2025 Wis. Act 210](#), section [17 \(2\)](#).

History: 1991 a. 277; 1993 a. 213; 1999 a. 109; 2001 a. 16 ss. [3445f](#), [3445g](#), [4060hd](#), [4060hw](#), [4060hy](#); 2009 a. 100, 121; 2017 a. 124; 2025 a. 210.

347.415 Odometer tampering. (1g) In this section, “odometer” means an instrument for measuring and recording the actual distance that a motor vehicle, snowmobile, all-terrain vehicle, or utility terrain vehicle has traveled while in operation, but does not include any auxiliary instrument designed to be reset to zero to measure and record the actual distance that a motor vehicle, snowmobile, all-terrain vehicle, or utility terrain vehicle has traveled on trips.

(1m) No person may, either personally or through an agent, remove, replace, disconnect, reset, tamper with, alter, or fail to connect the odometer of any motor vehicle, snowmobile, all-terrain vehicle, or utility terrain vehicle with the intent to change or affect the number of miles indicated thereon.

(2) No person may operate a motor vehicle subject to registration under ch. [341](#) on any street or highway with knowledge that the odometer is removed, disconnected or nonfunctional. An exemption may be provided if parts are on back order to correct a nonfunctional odometer.

(3) No person may advertise for sale, sell, use, install, or have installed any device which causes an odometer to register any mileage other than the true mileage driven. For purposes of this subsection, “true mileage driven” means that mileage traveled by the vehicle as measured and recorded by the odometer within the manufacturer’s design tolerance.

(4) No person shall conspire with any other person to violate sub. (1m), (2) or (3).

(5) Nothing in this section shall prevent the service, repair or replacement of an odometer, provided the mileage indicated thereon remains the same as before the service, repair or replacement. Where the odometer is incapable of registering the same mileage as before such service, repair or replacement, the odometer shall be adjusted to read zero, and a written notice shall be attached, by the owner or an agent, to the left door frame of the vehicle, or other location as prescribed by the department, specifying the mileage prior to service, repair or replacement of the odometer and the date on which it was serviced, repaired or replaced. No person may, with intent to defraud, remove or alter such a notice so affixed. No person who services, repairs or replaces an odometer that is incapable of registering the same mileage as before such service, repair or replacement may fail to adjust the odometer to read zero or fail to attach the notice required by this subsection.

History: 1975 c. 121, 199; 1977 c. 29 s. [1654 \(7\) \(a\)](#); 1993 a. 159; 2003 a. 166; 2011 a. 208.

Cross-reference: See also ch. [Trans 154](#), Wis. adm. code.

347.417 Immobilization device tampering. (1) No person may remove, disconnect, tamper with, or otherwise circumvent the operation of any immobilization device installed in response to a court order under s. [346.65 \(6\)](#), 1999 stats., or s. [343.301 \(2\)](#), 2007 stats. This subsection does not apply to the removal of an immobilization device pursuant to a court order or to necessary repairs to a malfunctioning immobilization device.

(2) The department shall design a warning label which shall be affixed by the owner of each immobilization device before the device is used to immobilize any motor vehicle under s. [346.65](#)

347.417 EQUIPMENT OF VEHICLES

Updated 23-24 Wis. Stats. 14

(6), 1999 stats., or s. 343.301 (2), 2007 stats. The label shall provide notice of the penalties for removing, disconnecting, tampering with, or otherwise circumventing the operation of the immobilization device.

History: 1991 a. 277; 1999 a. 109; 2001 a. 16 ss. 3445h to 3445m, 4060hg, 4060hj, 4060hw, 4060hy; 2009 a. 100.

347.42 Windshield wipers. No person may operate on a highway any motor vehicle equipped with a windshield, except a moped or motorcycle, unless the motor vehicle also is equipped with a device for cleaning rain, snow or other moisture from the windshield. The device shall be so constructed as to be controlled or operated by the operator of the vehicle and shall at all times be maintained in good working order.

History: 1979 c. 163; 1983 a. 243; 1985 a. 65; 2019 a. 50.

Cross-reference: See also s. Trans 305.35, Wis. adm. code.

347.43 Safety glass. (1g) In this section, “safety glass” means glass so treated or combined with other materials as to reduce, in comparison with ordinary sheet glass or plate glass, the likelihood of injury to persons by objects from external sources or by such glass when it is struck, cracked or broken.

(1s) No person may operate upon a highway any motor vehicle manufactured after January 1, 1936, except a recreational vehicle other than a 5th-wheel recreational vehicle, unless the motor vehicle is equipped with safety glass wherever glass is used on the motor vehicle in partitions, doors, windows or windshields.

(2) No person may sell any new motor vehicle unless such vehicle is equipped with safety glass in accordance with the requirements of sub. (1s).

(4) If a common carrier or person operating under a permit or certificate issued by the department is convicted of operating a vehicle in violation of this section, the department may suspend or revoke the permit or certificate until such time as the vehicle has been equipped with safety glass as required by this section.

History: 1977 c. 29 s. 1654 (9) (f); 1981 c. 347; 1985 a. 187; 1993 a. 16; 1999 a. 85; 2007 a. 60.

Cross-reference: See also ss. Trans 305.32 and 305.34, Wis. adm. code.

Sub. (1) [now sub. (1s)] requires that whenever broken glass is replaced in a vehicle it must be replaced with safety glass. Replacing glass with plastic violated this section, and an officer observing a vehicle with replacement plastic had probable cause to stop the vehicle for a violation of this section. *State v. Longcore*, 2001 WI App 15, 240 Wis. 2d 429, 623 N.W.2d 201, 00-1171.

347.435 Vehicle monitoring and feedback. Notwithstanding s. 346.88, a person may operate a vehicle that has a device mounted to the front windshield if all of the following apply:

(1) The device is designed to monitor the vehicle and provide feedback to the operator for the purpose of safety or improving vehicle operation.

(2) The device is mounted directly above, behind, or below the mirror required in s. 347.40 (1) or, if no mirror is present, at the location where the mirror would typically be mounted.

(3) The device is mounted in a manner consistent with applicable federal requirements if the vehicle is a commercial motor vehicle as defined in 49 CFR 390.5.

History: 2015 a. 160.

347.44 Painting requirements for school buses; restrictions as to painting of other vehicles. (1) All school buses shall be painted as follows:

(a) With the exception of trim, the body, including hood, fenders, cowl and roof shall be painted a uniform color, national school bus glossy yellow, according to national institute of standards and technology specifications;

(b) The body trim, if used, shall be black; and

(c) The words, “SCHOOL BUS”, in black letters at least 8 inches high shall appear on both the front and rear of the upper body area or on a sign attached thereto.

(2) A motor vehicle described in s. 340.01 (56) (b) may, but need not, comply with sub. (1). If the motor vehicle complies with sub. (1), the vehicle shall comply with other regulations relating to school buses prescribed by the department by rule.

(3) No person may paint or in any way designate a motor vehicle in the manner described in sub. (1) except as expressly authorized by this section.

(4) When a motor vehicle in compliance with sub. (1), s. 347.25 (2), and the rules of the department relating to school bus equipment is no longer operated as a school bus, the registration of the motor vehicle for another purpose may not be permitted until the owner:

(a) Physically removes the signs identifying the vehicle as a school bus, the lights required by s. 347.25 (2) and such other equipment as the department may specify by rule; and

(b) Repaints the entire vehicle to a color other than national school bus glossy yellow or any color commonly referred to as yellow.

History: 1975 c. 121, 199, 224, 429; 1977 c. 29 s. 1654 (7) (e); 1977 c. 228; 1979 c. 221; 1983 a. 175; 1985 a. 287; 1989 a. 165.

Cross-reference: See also ch. Trans 300, Wis. adm. code.

347.445 Crossing gates for school buses. No person may operate a school bus that is painted as provided in s. 347.44 unless it is equipped with a retractable crossing gate on the front of the bus that, when in use, prevents children from crossing in front of the school bus in such proximity that they are not visible to the operator of the school bus from the operator’s seat. The secretary shall prescribe rules for the specifications, installation, and operation of crossing gates required under this section.

History: 2001 a. 58.

347.446 Audiovisual recording on school buses. (1) Subject to sub. (2), a school bus may be equipped with a device for recording audio or video, or both, of the interior of the school bus while the school bus is being used to transport pupils to and from school and school-sponsored activities.

(2) Subsection (1) applies only if the applicable school board, the governing board of a charter school authorized under s. 118.40 (2r) or (2x), or the governing body of a private school or tribal school adopts a policy authorizing audiovisual recording on school buses and notice of the policy is provided to pupils and their parents or guardians and clearly posted on the interior of the school bus.

(3) Recordings made as authorized under this section shall remain confidential and may be used by only school officials and law enforcement personnel for investigations, school disciplinary actions, and criminal prosecutions related to incidents occurring in or around the bus.

History: 2025 a. 160.

347.447 Additional safety mirrors on school buses. A school bus that is painted as provided in s. 347.44 may be equipped with a supplemental mirror system, mounted on the passenger side of the school bus and designed to enhance operator visibility of children near the passenger side of the school bus, if the supplemental mirror system does not make inoperative or diminish the performance of any other mirror or safety device required on the school bus.

History: 2011 a. 223.

347.45 Tire equipment. (1) All automobiles, motor trucks, motor buses, truck tractors, trailers, semitrailers, recreational vehicles, and mobile homes when operated upon a highway shall be completely equipped with tires inflated with compressed air and all other motor vehicles when operated on a highway shall be equipped with tires of rubber or of some material or construction of equal resiliency. No person may operate on a highway any mo-

15 Updated 23-24 Wis. Stats.**EQUIPMENT OF VEHICLES****347.47**

tor vehicle, trailer, semitrailer, recreational vehicle, or mobile home having any metal tire in contact with the roadway, except that tire chains of reasonable proportions may be used when required for safety because of snow, ice or other conditions tending to cause a vehicle to skid, and except as provided in sub. (2) (c).

(2) No person shall operate on a highway any vehicle, including farm tractors, implements of husbandry, animal-drawn vehicles and road machinery, if such vehicle has on the periphery of any of its tires any block, stud, flange, cleat, spike or other protuberance of any material other than rubber which projects beyond the tread of the traction surface of the tire, except that:

(a) Farm tractors, implements of husbandry, bicycles, animal-drawn vehicles, and road machinery may be operated with metal tires or tires having protuberances that will not injure the highway.

(b) Tire chains of reasonable proportions may be used on any vehicle when required for safety because of snow, ice or other conditions tending to cause a vehicle to skid.

(c) A pneumatic tire may have embedded in it wire or wire coils for improving traction on ice and snow, but such tire shall be so constructed that the percentage of wire or wire coils in contact with the roadway does not exceed, after the first 1,000 miles of use or operation, 5 percent of the total tire area in contact with the roadway. During the first 1,000 miles of use or operation of any such tire the wire or wire coils in contact with the roadway shall not exceed 20 percent of the total tire area in contact with the roadway. Tires equipped with tungsten carbide studs shall be limited in usage and design as follows:

1. The department shall, by rule, designate the times of year during which any type of tire described in this paragraph may be used.

2. Such tires may be used only on authorized emergency vehicles, school buses, vehicles used to deliver mail and automobiles with out-of-state registrations and then only if such automobile is in the course of passing through this state for a period of not more than 30 days.

3. Such studs shall not project more than one-eighth inch beyond the tread surface of the tire.

(3) The authority in charge of maintenance of the highway in question may, in its discretion, issue a special permit authorizing operation upon such highway of a vehicle the operation of which would otherwise be prohibited under this section.

(4) No person shall knowingly operate on any highway any vehicle on which any tire has been regrooved or recut or offer such tire for sale or exchange. This subsection shall not apply to regrooved or recut commercial vehicle tires which are designed and constructed in such a manner that regrooving or recutting is an acceptable and safe practice, nor does this subsection apply to regrooving or recutting done in a tire recapping process.

(5) Notwithstanding sub. (2), an implement of husbandry equipped with rubber tracks or tracks made of equivalent material may be operated on a highway if such operation will not injure the highway.

History: 1973 c. 338; 1977 c. 29 s. 1654 (7) (a); 1985 a. 187; 1997 a. 102; 1999 a. 85; 2007 a. 11; 2009 a. 177; 2011 a. 73; 2015 a. 15, 232.

Cross-reference: See also ch. [Trans 306](#) and s. [Trans 305.30](#), Wis. adm. code.

347.455 Modifications to height of vehicle. (1) Except as further provided in this section, no person may operate any vehicle on a highway if modifications have been made to the suspension system, axles or chassis of the vehicle which cause any portion of the vehicle to ride more than 4 inches above the height of the vehicle specified by the manufacturer. The height of the vehicle shall be measured from the level surface on which the vehicle stands.

(2) If the modification is for the purpose of strengthening or

improving handling, modifications may be made to the suspension system, axles or chassis of a 4-wheel drive vehicle or a motor truck which has a gross weight of not more than 8,000 pounds which cause the vehicle to ride 5 or less inches above the height of the vehicle specified by the manufacturer. The height of the vehicle shall be measured from the level surface on which the vehicle stands.

(3) A 4-wheel drive vehicle or a motor truck which has a gross weight of not more than 8,000 pounds may be modified to use a tire and wheel size which exceeds the wheel and tire size specified by the manufacturer for the vehicle by up to 4 inches in radius.

(4) No person may operate any vehicle on a highway if modifications have been made to the suspension system, axles, chassis or exhaust system of the vehicle which cause any portion of the vehicle, except the tires, to extend below lines drawn from the bottom of each wheel rim to the points of contact between the tires on the opposite side and opposite end of the vehicle and the level surface on which the vehicle stands.

History: 1981 c. 216; 1993 a. 165.

Cross-reference: See also ss. [Trans 305.18](#), [305.29](#), and [305.31](#), Wis. adm. code.

347.46 Fenders and mudguards. (1) No person shall operate a vehicle of the tractor type on a highway unless the driving wheels of such vehicle are protected by suitable fenders.

(2) No person shall operate on a highway in intercity movement any privately owned motor truck or privately owned semitrailer drawn by a truck tractor, except those motor trucks and semitrailers equipped with dump bodies, unless such motor truck or semitrailer is equipped with rear fenders or mudguards of such material and so constructed and placed as to restrict to a minimum the splashing of water, mud or other material which may be thrown by the rear wheels. Such rear fenders or mudguards shall meet the following minimum specifications:

(a) The fenders or mudguards shall cover the tire or multiple tires they are protecting starting at the top from a line drawn vertically through the center of the axle and extending rearward and downward so that the fender or mudguard under any condition of operation or loading of the vehicle has a ground clearance of not more than one third of the horizontal distance from the center of the rearmost axle to the fender or mudguard;

(b) The fenders or mudguards shall be at least as wide as the tire or multiple tires they are protecting;

(c) If the vehicle is so designed and constructed that the rear wheels are covered in the manner specified in pars. (a) and (b) by means of fenders, body construction or other means of enclosure, then no special mudguards are required. Otherwise, the vehicle shall be equipped with special mudguards to the extent necessary to meet the requirements of pars. (a) and (b).

Cross-reference: See also ss. [Trans 305.22](#) and [305.53](#), Wis. adm. code.

347.47 Drawbars, trailer hitches and mobile home couplings. (1) No person shall operate a vehicle towing or drawing another vehicle or vehicles on a highway if the drawbar or other connection between any 2 vehicles exceeds 12 feet in length.

(2) No person shall operate a motor vehicle drawing a trailer, semitrailer, recreational vehicle, or mobile home upon a highway unless the hitch and coupling attaching the trailer, semitrailer, recreational vehicle, or mobile home to the vehicle by which it is drawn is of such construction as to cause such trailer, semitrailer, recreational vehicle, or mobile home to follow in direct line with the propelling vehicle without dangerous side swing or wobble. The hitch and coupling, the surface to which they are attached, and the connections, shall be of sufficient strength to prevent failure under all conditions of operation. The hitch is that part of the

347.47 EQUIPMENT OF VEHICLES

Updated 23-24 Wis. Stats. 16

connecting mechanism, including the coupling platform and its attaching members or weldments, which is attached to the towing vehicle. The coupling is that part of the connecting mechanism, including the coupling and its attaching members or weldments, which is attached to the trailer, recreational vehicle, or mobile home and by which connection is made to the hitch. If a device is used between the trailer proper and the coupling such as a pole, such device shall also meet the requirements of this section.

(3) In addition to the hitch and coupling specified in sub. (2), every towed vehicle shall be coupled to the towing vehicle by means of safety chains, leveling bars or cables. This requirement does not apply to a semitrailer having a connecting device composed of a 5th wheel and kingpin assembly, nor to a pole or pipe dolly. The safety chains, leveling bars or cables shall have only the necessary slack to permit proper turning and safety chains or cables shall be so connected to the towed and towing vehicle to prevent the drawbar from dropping to the ground if the hitch or coupling disengages. Two separate lengths of safety chain, leveling bars or cable shall be required on all trailers and mobile homes; however, the department may authorize use of such other appropriate equipment or methods approved by nationally recognized organizations which recommend safety standards for motor vehicles.

(4) Trailer, semitrailer, recreational vehicle, and mobile home couplings and the safety chains, leveling bars or cables shall be of such minimum strength, design and type as established by published rule of the department.

History: 1971 c. 88; 1977 c. 29 s. 1654 (7) (e); 1979 c. 34; 2007 a. 11.

Cross-reference: See also ch. [Trans 308](#) and s. [Trans 305.52](#), Wis. adm. code.

347.475 Airbags, prohibited practices. (1) In this section:

(a) “Airbag” means any component of a passive inflatable motor vehicle occupant crash protection system designed by a motor vehicle manufacturer to operate in the event of a collision and designed to meet federal motor vehicle safety standards for the specific make, model, and year of the motor vehicle in which it is or will be installed.

(b) “Counterfeit airbag” means a replacement airbag, or an airbag component, that displays an unauthorized mark substantially similar to the mark of an original equipment manufacturer or a genuine supplier of parts to the manufacturer of a motor vehicle.

(c) “Nonfunctional airbag” means a replacement airbag to which any of the following applies:

1. The replacement airbag was previously deployed or damaged.

2. The replacement airbag has an electric fault that is detected by the motor vehicle’s diagnostic system when the installation procedure is completed and the motor vehicle is returned to the motor vehicle owner or transferred to a new owner.

3. The replacement airbag includes a part or object intended to mislead the owner or operator of the motor vehicle into believing that a functional airbag has been installed.

4. The replacement airbag is prohibited from being sold under [49 USC 30120](#) (j).

(d) “Replacement airbag” means an airbag intended to replace an original equipment manufacturer’s airbag that is faulty, has deployed, was stolen, has been recalled, or is part of a motor vehicle restoration.

(2) No person may, either personally or through an agent, import, manufacture, sell, offer for sale, install, reinstall, or distribute any previously deployed airbag or nonfunctional airbag. This subsection does not apply to the sale or transfer of a motor vehicle with a previously deployed airbag unless the deployment is concealed or disguised.

(3) No person may, either personally or through an agent, remove, disconnect, tamper with, or otherwise circumvent the operation of any airbag, except for the purpose of testing, repairing, or maintaining an airbag, salvaging an undeployed airbag, disposing of a deployed airbag, or replacing a deployed airbag with a functional airbag. This subsection does not apply to the installation or use of an on-off switch by any person who is authorized by federal law or regulation to install or use an on-off switch for an airbag.

(4) No person may, either personally or through an agent, install a cover or otherwise conceal or disguise a missing airbag or a previously deployed airbag.

(5) No person may, either personally or through an agent, import, manufacture, sell, offer for sale, install, reinstall, or distribute a counterfeit airbag.

(6) This section does not apply to any of the following:

(a) A person installing, reinstalling, or replacing an airbag or other component of a passive inflatable motor vehicle occupant crash protection system in a motor vehicle used exclusively for police work.

(b) An owner or employee of a motor vehicle dealership or the owner of a motor vehicle who, before the sale of the vehicle, does not have knowledge that the vehicle’s airbag, or another component of the vehicle’s passive inflatable motor vehicle occupant crash protection system is counterfeit or nonfunctional.

(c) A person who transfers a vehicle title to an insurance company to satisfy an insurance claim when the insurance company declares the motor vehicle to be an actual total loss or constructive total loss.

(d) An insurance company, salvage yard, or other entity that sells, recycles, or otherwise disposes of a motor vehicle as authorized by law or regulation.

History: 2001 a. 28; 2025 a. 97.

347.48 Safety belts and child safety restraint systems.

(1) **SAFETY BELTS REQUIRED.** (a) No person may buy, sell, lease, trade or transfer a motor vehicle other than an automobile at retail from or to Wisconsin residents unless the vehicle is equipped with safety belts installed for use as required under [49 CFR 571](#), and no such vehicle may be operated in this state unless such belts remain installed.

(b) No person may buy, sell, lease, trade or transfer an automobile that is required under [49 CFR 571](#) to be equipped with safety belts from or to a resident of this state unless the front designated seating positions of the automobile are equipped with safety belts installed for use as required under [49 CFR 571](#) and unless each rear outboard designated seating position of the automobile is equipped with a safety belt consisting of a combination of a pelvic and upper torso restraint that conforms to standards for a Type 2 seat belt assembly under [49 CFR 571.209](#), and no automobile may be operated in this state unless such belts remain installed. Nothing in this section applies to antique reproductions.

(2) **TYPE AND MANNER OF INSTALLING.** All such safety belts must be of a type and must be installed in a manner approved by the department. The department shall establish specifications and requirements for approved types of safety belts and attachments thereto. The department will accept, as approved, all seat belt installations and the belt and anchor meeting the society of automotive engineers’ specifications.

(2m) **REQUIRED USE.** (a) In this subsection, “properly restrained” means wearing a safety belt approved by the department under sub. (2) and fastened in a manner prescribed by the manufacturer of the safety belt which permits the safety belt to act as a body restraint.

(b) If a motor vehicle is required to be equipped with safety

17 Updated 23-24 Wis. Stats.

EQUIPMENT OF VEHICLES

347.48

belts in this state, no person may operate that motor vehicle unless the person is properly restrained in a safety belt.

(c) If a motor vehicle is required to be equipped with safety belts in this state, no person may operate that motor vehicle unless each passenger who is at least 8 years old and who is seated at a designated seating position in the front seat required under 49 CFR 571 to have a safety belt installed or at a designated seating position in the seats, other than the front seats, for which a safety belt is required to be installed is properly restrained.

(d) If a motor vehicle is required to be equipped with safety belts in this state, no person who is at least 8 years old and who is seated at a designated seating position in the front seat required under 49 CFR 571 to have a safety belt installed or at a designated seating position in the seats, other than the front seats, for which a safety belt is required to be installed may be a passenger in that motor vehicle unless the person is properly restrained.

(dm) Paragraphs (b), (c) and (d) do not apply to the operation of an authorized emergency vehicle by a law enforcement officer or other authorized operator under circumstances in which compliance could endanger the safety of the operator or another.

(dr) Paragraph (b) does not apply to the operator of a vehicle while on a route which requires the operator to make more than 10 stops per mile involving an exit from the vehicle in the scope of his or her employment. Paragraphs (c) and (d) do not apply to a passenger while on a route which requires the passenger to make more than 10 stops per mile involving an exit from the vehicle in the scope of his or her employment.

(e) The department shall, by rule, exempt from the requirements under pars. (b) to (d) persons who, because of a physical or medical condition, cannot be properly restrained in a safety belt.

Cross-reference: See also ch. Trans 315, Wis. adm. code.

(f) 1. This subsection does not apply if the motor vehicle is a taxicab or is not required to be equipped with safety belts under sub. (1) or 49 CFR 571.

2. This subsection does not apply to a privately owned motor vehicle while being operated by a rural letter carrier for the delivery of mail or while being operated by a delivery person for the delivery of newspapers or periodicals.

3. This subsection does not apply to a motor vehicle while being operated by a land surveying crew while conducting a land survey along or upon the highway.

7. This subsection does not apply to a farm truck or dual purpose farm truck while being used in conjunction with the planting or harvesting of crops and not being operated upon the highway.

(g) Evidence of compliance or failure to comply with par. (b), (c) or (d) is admissible in any civil action for personal injuries or property damage resulting from the use or operation of a motor vehicle. Notwithstanding s. 895.045, with respect to injuries or damages determined to have been caused by a failure to comply with par. (b), (c) or (d), such a failure shall not reduce the recovery for those injuries or damages by more than 15 percent. This paragraph does not affect the determination of causal negligence in the action.

(gm) A law enforcement officer may not take a person into physical custody solely for a violation of this subsection or sub. (1) or (2) or a local ordinance in conformity with this subsection, sub. (1) or (2) or rules of the department.

(3m) SAFETY BELT INFORMATION PROGRAM. The department shall develop and administer a public information program to promote safety belt awareness and use.

(4) CHILD SAFETY RESTRAINT SYSTEMS REQUIRED; STANDARDS; EXEMPTIONS. (ag) In this subsection:

1. “Child booster seat” means a child passenger restraint system that meets the applicable federal standards under 49 CFR 571.213 and is designed to elevate a child from a vehicle seat to

allow the vehicle’s safety belt to be properly positioned over the child’s body.

2. “Designated seating position” has the meaning given in 49 CFR 571.3.

3. “Properly restrained” means any of the following:

a. With respect to par. (as) 1. and 2., fastened in a manner prescribed by the manufacturer of the child safety restraint system which permits the system to act as a body restraint but does not include a system in which the only body restraint is a safety belt of the type required under sub. (1).

b. With respect to par. (as) 3., wearing a safety belt consisting of a combination lap belt and shoulder harness approved by the department under sub. (2) and fastened in a manner prescribed by the manufacturer of the safety belt so that the safety belt properly fits across the child’s lap and the center of the child’s chest in a manner appropriate to the child’s height, weight, and age that permits the safety belt to act as a body restraint.

c. With respect to par. (as) 4., fastened in a manner prescribed by the manufacturer of the system which permits the system to act as a body restraint.

(am) No person may transport a child under the age of 8 in a motor vehicle unless the child is restrained in compliance with par. (as) in a safety restraint system that is appropriate to the child’s age and size and that meets the standards established by the department under this paragraph. The department shall, by rule, establish standards in compliance with applicable federal standards, including standards under 49 CFR 571.213, for child safety restraint systems.

(as) A child under the age of 8 years who is being transported in a motor vehicle shall be restrained as follows:

1. If the child is less than one year old or weighs less than 20 pounds, the child shall be properly restrained in a rear-facing child safety restraint system, positioned at a designated seating position in a back passenger seat of the vehicle if the vehicle is equipped with a back passenger seat.

2. Subject to subd. 1., if the child is at least one year old and weighs at least 20 pounds but is less than 4 years old or weighs less than 40 pounds, the child shall be properly restrained as provided in subd. 1. or properly restrained in a forward-facing child safety restraint system, positioned at a designated seating position in a back passenger seat of the vehicle if the vehicle is equipped with a back passenger seat.

3. Subject to subds. 1. and 2., if the child is at least 4 years old but less than 8 years old, weighs at least 40 pounds but not more than 80 pounds, and is not more than 57 inches in height, the child shall be properly restrained as provided in subd. 2. or properly restrained in a child booster seat.

4. Subject to subds. 1. to 3., if the child is less than 8 years old, the child shall be properly restrained as provided in subds. 1. to 3. or properly restrained in a safety belt approved by the department under sub. (2).

(b) The department may, by rule, exempt from the requirements under pars. (am) and (as) any child who because of a physical or medical condition or body size cannot be placed in a child safety restraint system, child booster seat, or safety belt.

(c) This subsection does not apply if the motor vehicle is a motor bus, school bus, taxicab, moped, motorcycle or is not required to be equipped with safety belts under sub. (1) or 49 CFR 571.

(d) Evidence of compliance or failure to comply with pars. (am) and (as) is admissible in any civil action for personal injuries or property damage resulting from the use or operation of a motor vehicle but failure to comply with pars. (am) and (as) does not by itself constitute negligence.

History: 1975 c. 337; 1977 c. 29 s. 1654 (7) (a); 1981 c. 327; 1983 a. 285; 1987

347.48 EQUIPMENT OF VEHICLES

Updated 23-24 Wis. Stats. 18

a. 132 ss. 3 to 6, 11; 1987 a. 399; 1989 a. 22; 1991 a. 26, 39, 198, 269; 1997 a. 190; 2005 a. 106; 2009 a. 28; 2011 a. 111.

Cross-reference: See also ch. [Trans 310](#) and s. [Trans 305.27](#), Wis. adm. code.

“Seat belt negligence” and “passive negligence” are distinguished. Jury instructions regarding seat belts are recommended. A method for apportioning damages in seat belt negligence cases is adopted. *Foley v. City of West Allis*, [113 Wis. 2d 475, 335 N.W.2d 824](#) (1983).

A common law action for contribution may not be brought against a person who violates sub. (2m) (g). *Gaertner v. Holcka*, [219 Wis. 2d 436, 580 N.W.2d 271](#) (1998), [96-2726](#).

A statute requiring the wearing of seat belts in motor vehicles would be constitutional. 58 Atty. Gen. 241.

The seat belt defense — state of the law. *Kircher*, 53 MLR 172.

The seat belt defense — the trial lawyer’s view. *Bowman*, 53 MLR 191.

Practical defense problems — the expert’s view. *Huelke*, 53 MLR 203.

The seat belt as a cause of injury. *Snyder*, 53 MLR 211.

347.485 Protective headgear for use on motorcycles.

(1) (a) No person who holds an instructional permit under s. [343.07](#) (4) or who is under 18 years of age may operate or ride upon a motorcycle on any highway unless the person is wearing protective headgear of a type which meets the standards established for motorcycle operation in [49 CFR 571.218](#) and the chin strap is properly fastened.

(am) No person may operate a motorcycle when carrying a passenger under 18 years of age unless the passenger is wearing protective headgear.

(b) No person may sell or offer for sale any protective headgear for use by a driver or passenger on a motorcycle, not meeting the standards established for motorcycle operation in [49 CFR 571.218](#).

(2) (a) No person may operate a motorcycle on any highway without wearing any of the following eye protection:

1. A protective face shield attached to the headgear.
2. Glasses.
3. Goggles.

(b) Except for photosensitive corrective glasses prescribed by an ophthalmologist, physician, oculist or optometrist, eye protection worn during hours of darkness may not be tinted or darkened.

(c) Notwithstanding par. (a), if the vehicle is an auticycle equipped with a windshield or a motorcycle equipped with a windshield that rises a minimum of 15 inches above the handlebar, the use of other eye protective devices is not mandatory.

(d) This subsection shall not apply to persons operating a motorcycle in a parade sanctioned by the local municipality.

(3) No person may rent, lease or loan a motorcycle to another unless he or she has ascertained that such party has the required eye protection and, if the party holds an instructional permit under s. [343.07](#) (4) or is under 18 years of age, that the party has the required protective headgear for operating the motorcycle.

(4) Every person in the motorcycle rental business shall have clean, usable protective headgear for rent in sufficient quantity to care for the needs of all customers.

History: 1977 c. 29 s. 1654 (7) (e); 1977 c. 204, 447; 1983 a. 133, 243, 538; 1985 a. 65, 85; 2019 a. 50.

Three-wheeled trucks and automobiles, golf carts, and other special purpose vehicles such as street sweepers, industrial fork-lifts, and motorized wheelbarrows are not motorcycles, and operators are not subject to this section. 58 Atty. Gen. 17.

347.486 General requirements. (1) No person may operate a motorcycle if the handlegrips of the handlebars rise more than 30 inches above the lowest point of the top of the driver’s seat when the seat is occupied.

(2) No person may operate a motorcycle with an improvised, defective or repaired handlebar.

(3) No person may operate a motorcycle without a functioning muffler.

History: 1979 c. 163; 1983 a. 243; 1985 a. 65; 2019 a. 50.

Cross-reference: See also subch. III of ch. [Trans 305](#), Wis. adm. code.

347.487 Seating requirements. Except as provided in s. [346.595](#) (3m), no more than 2 persons may ride on a motorcycle during operation, and then only if the vehicle is equipped and designed with adequate seats and foot rests or pegs. Foot rests or pegs shall be mounted in accordance with manufacturer’s specifications. In the absence of manufacturer’s specifications, foot rests or pegs for the passenger shall be located on the same horizontal plane as those of the operator.

History: 1983 a. 243; 1985 a. 65; 2019 a. 50.

347.488 Moped equipment. No person may operate a moped unless:

(1) The moped complies with all federal emission, equipment and safety standards applicable at the time of manufacture;

(2) None of the original equipment installed on the moped by the manufacturer has been replaced with equipment of lesser performance characteristics; and

(3) The performance characteristics of the moped have not been altered so as to enable it to exceed the maximum design speed authorized for a moped under s. [340.01](#) (29m).

History: 1977 c. 288.

347.489 Lamps and other equipment on bicycles and other vehicles and devices.

(1) No person may operate a bicycle, motor bicycle, personal delivery device, electric scooter, or electric personal assistive mobility device upon a highway, sidewalk, bicycle lane, or bicycle way during hours of darkness unless the bicycle, motor bicycle, personal delivery device, electric scooter, or electric personal assistive mobility device is equipped with or, with respect to a bicycle or motor bicycle, the operator is wearing, a lamp emitting a white light visible from a distance of at least 500 feet to the front of the bicycle, motor bicycle, personal delivery device, electric scooter, or electric personal assistive mobility device. A bicycle, motor bicycle, personal delivery device, electric scooter, or electric personal assistive mobility device shall also be equipped with a red reflector that has a diameter of at least 2 inches of surface area or, with respect to an electric scooter or an electric personal assistive mobility device, that is a strip of reflective tape that has at least 2 square inches of surface area, on the rear so mounted and maintained as to be visible from all distances from 50 to 500 feet to the rear when directly in front of lawful upper beams of headlamps on a motor vehicle. A lamp emitting a steady or flashing red light visible from a distance of 500 feet to the rear may be used in lieu of the red reflector.

(1m) No person may operate a personal delivery device upon a sidewalk unless the device is equipped with a braking system that, when engaged, will enable the personal delivery device to come to a controlled stop.

(2) No person may operate a bicycle, motor bicycle, electric scooter, or electric personal assistive mobility device upon a highway, bicycle lane, or bicycle way unless it is equipped with a brake in good working condition, adequate to control the movement of and to stop the bicycle, motor bicycle, electric scooter, or electric personal assistive mobility device whenever necessary.

(3) No bicycle, motor bicycle, electric scooter, or electric personal assistive mobility device may be equipped with nor may any person riding upon a bicycle, motor bicycle, electric scooter, or electric personal assistive mobility device use any siren or compression whistle.

(3m) (a) 1. After January 1, 2018, a manufacturer or distributor of electric bicycles shall permanently affix to the electric bicycle a label containing all of the following information in Arial font of a minimum size of 9 point:

- a. The classification number of the electric bicycle.

19 Updated 23-24 Wis. Stats.**EQUIPMENT OF VEHICLES****347.50**

b. The speed at which the motor will cease to provide assistance or power.

c. The wattage of the motor equipped to the electric bicycle.

2. If a person modifies an electric bicycle so as to change the classification of the electric bicycle, the person shall prepare and affix to the electric bicycle a revised label satisfying the requirements of subd. 1.

(b) An electric bicycle shall meet the requirements of **16 CFR Part 1512**, as if the electric bicycle were a bicycle as defined under **16 CFR 1512.2 (a)**.

(c) An electric bicycle shall operate so that the motor ceases to provide assistance or power when the brakes are applied or the motor ceases to provide assistance or power when the rider stops pedaling.

(d) No person may operate a class 3 electric bicycle unless the electric bicycle is equipped with a speedometer that with reasonable accuracy registers the speed of the electric bicycle in miles per hour.

(4) No person may operate a personal delivery device upon a sidewalk unless the device is equipped with a plate or marker that is in a position to be clearly visible and that identifies the name and contact information of the personal delivery device operator.

History: 1973 c. 182, 333; 1977 c. 208; 1983 a. 243 s. 39; Stats. 1983 s. 347.489; 1995 a. 138; 2001 a. 90; 2011 a. 73; 2017 a. 13; 2019 a. 11, 34.

347.49 Equipment of vehicles transporting flammable liquids. (1) In this section, “flammable liquid” means any gasoline, naphtha, benzine, fuel oil, crude oil, kerosene or other liquid which has a flashpoint of 80 degrees Fahrenheit or less as determined by a Tagliabue or equivalent closed-cup test device.

(2) No person shall transport in or on any motor vehicle, trailer or semitrailer upon a highway any flammable liquid except by tank mounted on or attached to or structurally a part of such motor vehicle, trailer or semitrailer and which is plainly marked to show that flammable liquids are being transported therein.

(3) This section does not apply to transportation of flammable liquids as freight only by the consumer from the place of purchase to the place of consumption if such liquids are transported in drums or other containers having a capacity of not more than 100 gallons each and if the total amount of such liquids so transported in any one vehicle or combination of vehicles does not exceed 500 gallons.

History: 2017 a. 365 s. 111.

347.495 Registration plate concealment device. (1) In this section, “registration plate concealment device” means a manual, electronic, or mechanical device designed or adapted to be installed on a motor vehicle to do any of the following:

(a) Switch between 2 or more registration plates.

(b) Move, obstruct, or conceal a registration plate.

(c) Alter the appearance of a registration plate so that the registration number cannot be seen and read.

(2) No person may possess, sell, purchase, install, or use a registration plate concealment device.

(3) No motor vehicle may be equipped with a registration plate concealment device.

(4) Any motor vehicle equipped in violation of sub. (3) may be impounded. A vehicle impounded under this subsection shall be returned to the owner upon payment of reasonable costs of towing and impounding the vehicle.

History: 2025 a. 37.

347.50 Penalties. (1) Any person violating ss. 347.35 to 347.49, except s. 347.385 (5), s. 347.413 (1) or s. 347.415 (1m), (2) and (3) to (5) or s. 347.417 (1) or s. 347.475 or s. 347.48 (2m)

or (4) or s. 347.489, may be required to forfeit not less than \$10 nor more than \$200.

NOTE: Sub. (1) is amended by **2025 Wis. Act 210** eff. on the first day of the 12th month beginning after the date specified in the Department of Transportation notice published in the Wisconsin Administrative Register under **2025 Wis. Act 210**, section 17 (2), to read:

(1) Any person violating ss. 347.35 to 347.49, except s. 347.385 (5), or s. 347.415 (1m), (2) and (3) to (5) or s. 347.417 (1) or s. 347.475 or s. 347.48 (2m) or (4) or s. 347.489, may be required to forfeit not less than \$10 nor more than \$200.

(1m) Any person violating s. 347.385 (5) may be fined not more than \$10,000 or imprisoned for not more than one year in the county jail, or both, for each violation.

(1s) Any person violating s. 347.413 (1) or 347.417 (1) may be fined not less than \$150 nor more than \$600, or may be imprisoned for not more than 6 months, or both for the first offense. For a 2nd or subsequent conviction within 5 years, the person may be fined not less than \$300 nor more than \$1,000, or imprisoned for not more than 6 months, or both.

NOTE: Sub. (1s) is amended by **2025 Wis. Act 210** eff. on the first day of the 12th month beginning after the date specified in the Department of Transportation notice published in the Wisconsin Administrative Register under **2025 Wis. Act 210**, section 17 (2), to read:

(1s) Any person violating s. 347.417 (1) may be fined not less than \$150 nor more than \$600, or may be imprisoned for not more than 6 months, or both, for the first offense. For a 2nd or subsequent conviction within 5 years, the person may be fined not less than \$300 nor more than \$1,000, or imprisoned for not more than 6 months, or both.

(1t) In addition to the penalty under sub. (1s), if a person who is subject to an order under s. 343.301 violates s. 347.413, the court shall extend the order restricting the person’s operating privilege under s. 343.301 (1g) or (2m) for 6 months for each violation.

NOTE: Sub. (1t) is repealed by **2025 Wis. Act 210** eff. on the first day of the 12th month beginning after the date specified in the Department of Transportation notice published in the Wisconsin Administrative Register under **2025 Wis. Act 210**, section 17 (2).

(2) Any person violating s. 347.415 (1m), (2), and (3) to (5) may be fined not more than \$5,000 or imprisoned for not more than one year in the county jail, or both, for each violation.

(2e) (a) Except as provided in pars. (b) to (e), any person violating s. 347.475 may be fined not more than \$5,000 or imprisoned for not more than one year in the county jail, or both.

(b) Except as provided in pars. (c) to (e), any person violating s. 347.475 is guilty of a Class I felony for a 2nd or subsequent violation.

(c) Any person violating s. 347.475 is guilty of a Class H felony if the violation resulted in bodily harm, as defined in s. 939.22 (4), to a person.

(d) Any person violating s. 347.475 is guilty of a Class G felony if the violation resulted in great bodily harm, as defined in s. 939.22 (14), to a person.

(e) Any person violating s. 347.475 is guilty of a Class F felony if the violation resulted in the death of a person.

(2m) (a) Any person who violates s. 347.48 (2m) (b) or (c) and any person 16 years of age or older who violates s. 347.48 (2m) (d) shall be required to forfeit \$10.

(b) No forfeiture may be assessed for a violation of s. 347.48 (2m) (d) if the violator is less than 16 years of age when the offense occurs.

(3) (a) Any person violating s. 347.48 (4) (am) may be required to forfeit not less than \$30 nor more than \$75 if the child is less than 4 years old.

(b) No forfeiture may be assessed under par. (a) if all of the following apply:

1. The motor vehicle was not equipped with a child safety restraint system meeting the requirements under s. 347.48 (4) (am) at the time the uniform traffic citation was issued.

2. The person provides proof that, within 30 days after the

347.50 EQUIPMENT OF VEHICLES

Updated 23-24 Wis. Stats. 20

uniform traffic citation was issued, a child safety restraint system meeting the requirements under s. 347.48 (4) (am) was purchased or leased and properly installed in the motor vehicle.

3. The person has not, within the immediately preceding 3 years, been issued a uniform traffic citation for a violation of s. 347.48 (4) (am).

(4) Any person violating s. 347.48 (4) (am) may be required to forfeit not less than \$10 nor more than \$25 for the first offense if the child is at least 4 years old and less than 8 years old. For a

2nd or subsequent conviction within 3 years involving a child who is at least 4 years old and less than 8 years old, a person may be required to forfeit not less than \$25 nor more than \$200.

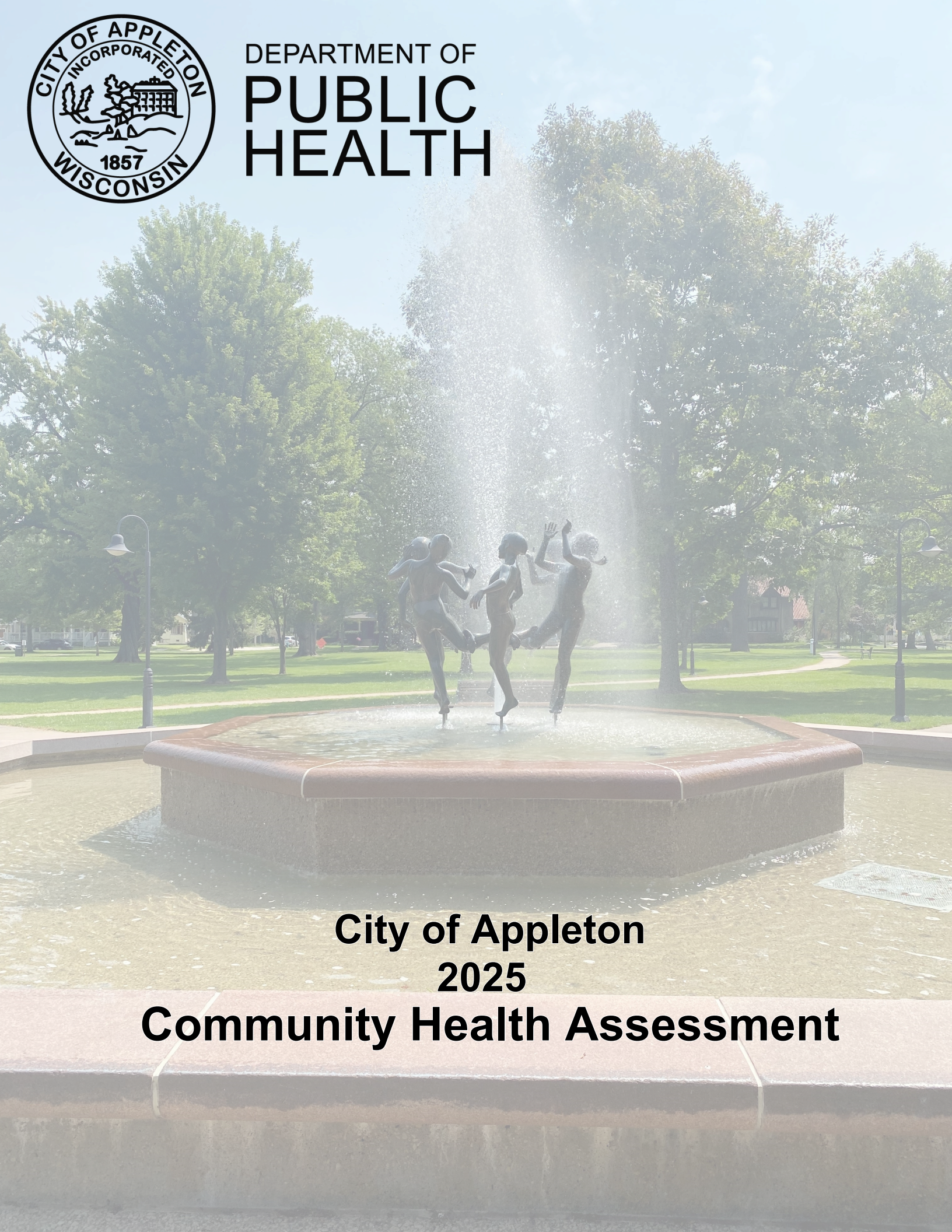
(5) Any person violating s. 347.489 may be required to forfeit not more than \$20.

(6) Any person violating s. 347.495 may be fined not more than \$1,000 or imprisoned for not more than 90 days, or both.

History: 1971 c. 278; 1975 c. 121; 1981 c. 327; 1983 a. 243; 1985 a. 309; 1987 a. 132; 1989 a. 22; 1991 a. 26, 277; 2001 a. 28; 2003 a. 166; 2005 a. 106, 193; 2007 a. 97; 2009 a. 28, 100; 2017 a. 124; 2025 a. 37, 97, 210.



DEPARTMENT OF
**PUBLIC
HEALTH**



**City of Appleton
2025
Community Health Assessment**

Who We Are



DEPARTMENT OF **PUBLIC HEALTH**

Vision

Health for all, together.

Mission

Facilitate equitable community wellbeing through education, health promotion, and response to public health needs.



Table of Contents

Introduction	
• Mission & Vision	2
• Table of Contents	3
• Terms & Definitions	4
• Letter from the Director	6
• Methodology	7
• Timeline	9
Community Health Assessment Best Practices	10
• Frameworks & Models	10
• Demographic Snapshot of Appleton	13
• Executive Summary	14
Factors Contributing to Health: Economic Stability	15
• Employment	15
• Income	16
• Cost of Living	18
• Financial Stress	20
Factors Contributing to Health: Neighborhood & Built Environment	23
• Housing	23
• Physical Environment	27
• Transportation	28
• Childcare	29
Factors Contributing to Health: Education Access & Quality	30
Factors Contributing to Health: Social & Community Context	32
• Social Connectedness	32
• Civic Engagement	36
• Community Safety	37
Factors Contributing to Health: Healthcare Access & Quality	39
• Access to Care	39
• Insurance	42
Factors Contributing to Health: Health Behaviors	43
• Food & Nutrition	43
• Substance Use	44
• Mental Health	47
• Chronic Disease	51
• Sexual Activity	52
Health Outcomes	53
• Cause of Death	53
Conclusion	54
• Next Steps	54
• References	55
• Appendix A: Community Concerns Survey	59
• Appendix B: Quadrants Analyzation	78
• Appendix C: Secondary Data	118

Terms & Definitions

Common Terms in Public Health

Barriers to Care Barriers to receiving needed health care can include cost, language or knowledge barriers, and structural or logistical factors, such as long waiting times and not having transportation. Barriers to care contribute to socioeconomic, racial and ethnic, and geographic differences in health care utilization and health status.

mchb.hrsa.gov/whusa11/hsu/downloads/pdf/303bcunc.pdf

Community Health Community health is a field within public health concerned with the study and improvement of the health of biological communities. Community health tends to focus on geographic areas rather than people with shared characteristics.

dictionary.reference.com/browse/community+health

Data Data are factual information (as measurements or statistics) used as a basis for reasoning, discussion, or calculation. Information in numerical form that can be digitally transmitted or processed.

merriam-webster.com/dictionary/data

Environmental Public Health Environmental health is the science and practice of preventing human injury and illness and promoting well-being by: identifying and evaluating environmental sources and hazardous agents; and limiting exposures to hazardous physical, chemical, and biological agents in air, water, soil, food, and other environmental media or settings that may adversely affect human health.

neha.org/pdf/positions/NEHA_Adopted_EH_Definition_July_2013.pdf

Epidemiology Epidemiology is the study of the distribution and determinants of health conditions or events among populations and the application of that study to control health problems.

Centers for Disease Control and Prevention (US). Principles of Epidemiology in Public Health Practice, 3rd ed. No date [cited 2012 Nov 6]

Health Disparities Health disparities are differences in population health status (incidence, prevalence, mortality, and burden of adverse health conditions) that can result from environmental, social and/or economic conditions, as well as public policy. These differences exist among specific population groups in the United States and are often preventable.

Adapted from: National Association of County and City Health Officials (US). Operational Definition of a Functional Local Health

Department [online]. 2005 [cited 2012 Nov 8]. Available from URL <http://www.naccho.org/topics/infrastructure/accreditation/OpDef.cfm>.

National Cancer Institute (US). Health Disparities Defined [online]. 2010 [cited 2012 Nov 8] <http://crchd.cancer.gov/disparities/defined.html>

Health Equity Health equity is the attainment of the highest level of health for all people. Achieving health equity requires valuing everyone equally with focused and ongoing societal efforts to address avoidable inequalities, historical and contemporary injustices, and the elimination of health and healthcare disparities.

<http://minorityhealth.hhs.gov/npa/templates/browse.aspx?lvl=1&lvlid=34>

Terms & Definitions

Common Terms in Public Health, continued

Health Inequity Health inequity refers to differences in population health status and mortality rates that are systemic, patterned, unfair, unjust, and actionable, as opposed to random or caused by those who become ill.

Margaret M. Whitehead, "The Concepts and Principles of Equity and Health," 22(3) International Journal of Health Services (1992): 429-445.

Practice-based Evidence is the incorporation of evidence grounded in cultural values, beliefs, and traditional practices.

Public Health Accreditation Board. Standards and Measures Version 1.5. Alexandria, VA, May 2011

Prevention Primary prevention consists of strategies that seek to prevent the occurrence of disease or injury, generally through reducing exposure or risk factor levels. These strategies can reduce or eliminate causative risk factors (risk reduction). Secondary prevention consists of strategies that seek to identify and control disease processes in their early stages before signs and symptoms develop (screening and treatment). Tertiary prevention consists of strategies that prevent disability by restoring individuals to their optimal level of functioning after a disease or injury is established.

(Turnock. Public Health: What It Is and How It Works (4th Ed). Jones and Bartlett. MA. 2009)ants of health [online]. 2012 [cited 2012 Nov 7].http://www.who.int/social_determinants/en/

Primary Data Primary data are data observed or collected from original sources, ranging from more scientifically rigorous approaches such as randomized controlled trials to less rigorous approaches such as case studies.

www.nlm.nih.gov

Secondary Data Secondary data are those data which have been collected in the past, collected by other parties, or result from combining data or information from existing sources.

www.nlm.nih.gov/nichs

Social Determinants of Health Social determinants of health are the conditions in which people are born, grow, live, work and age, including the health system. These circumstances are shaped by the distribution of money, power and resources at global, national and local levels. The social determinants of health are mostly responsible for health inequities – the unfair and avoidable differences in health status seen within and between countries.

(World Health Organization (Switzerland). Health Topics: Social determinants of health [online]. 2012 [cited 2012 Nov 7].http://www.who.int/social_determinants/en/

Letter from the Director

Appleton friends and neighbors,

Over the past year Appleton opened a remarkable conversation about health. We heard from more than a thousand residents in six languages, gathering perspectives everywhere from senior-center lunches to college commons, from neighborhood parks to emergency shelters. Your stories, paired with local, state, and national data, became our 2025 Community Health Assessment (CHA).

The narrative that emerged is clear and compelling. First, money matters. A single missed paycheck could topple roughly one-third of Appleton households, illustrating how financial strain seeps into every corner of well-being. Home matters as well. Fewer than four in ten residents believe safe, affordable housing is truly within reach, reminding us that health begins where we live and sleep. Connection matters, too. Nine out of ten respondents perceive unmet mental-health needs, and a growing share describe feeling isolated even among our busiest neighborhoods. Finally, equity matters. Health outcomes still diverge along lines of race, income, language, ability, sexual identity, and gender, underscoring that inequity is not an abstract concept but a daily reality that costs many the opportunity to thrive.

Because these themes echo across county lines, those insights are already woven into the Tri-County Community Health Assessment that will anchor a single regional Community Health Improvement Plan (CHIP) for Calumet, Outagamie, and Winnebago Counties. Appleton's data will sit shoulder-to-shoulder with findings from our neighbors as we draft a regional CHIP. This spring residents from all three counties will rank shared priorities. By fall, we will publish goals, metrics, and accountability measures that belong to the entire Fox Cities area. Each year we will report back, celebrating progress and recalibrating where needed.

You can help keep this story moving. Watch for upcoming forums, lend your expertise, and continue everyday acts that strengthen the social fabric—checking on a neighbor, volunteering, or advocating for policies that make housing and health care affordable. Together we will transform these findings into action and write the next chapter in a healthier, more equitable Appleton—and Tri-County region.



Dr. Charles E Sepers, Jr, PhD, MPH
Health Officer | Director



Methodology

Purpose: What is a Community Health Assessment?

Every five years, local health departments are statutorily required to conduct a Community Health Assessment to better understand the assets and needs of their community. A Community Health Assessment (CHA) is a look at the health status and needs of a community. It involves gathering, analyzing, and interpreting data about health, including demographics, health behaviors, access to healthcare services, environmental factors, and social determinants of health.

The primary goal of a CHA is to identify the health priorities, strengths, and challenges within the community. This informs decision-making processes, resource allocation, and interventions aimed at improving health outcomes and promoting equity.

Approach: What does the CHA involve?

Steering Committee

The steering committee for Appleton's Community Health Assessment was intentionally asked to represent a diverse set of stakeholders that represent critical sectors within the community. Those asked to join the committee, and those who accepted, are experts within a few key areas we wished to have represented in our assessment: children; youth; families; cultural diversity; and mental health.

Steering Committee		
Kayla McNamara	Boys & Girls Club of the Fox Valley	Children; Youth; Families; Cultural Diversity
Laura Jackson	Appleton Area School District	Children; Youth; Families
Kenny Yarborough	Lawrence University	College; Cultural Diversity
Wendy Krueger	United Way Fox Cities	Non-Profit; Fundraising
Megan Zimmerman	NAMI Fox Valley	Non-Profit; Mental Health
Beth Clay	NEW Mental Health Connection	Mental Health
Pa Khang	HMong American Partnership	Cultural Diversity
Breanna Mekuly	Appleton Health Department	Local Health Department
Jena McNiel	Appleton Health Department	
Sonja Jensen	Appleton Health Department	
Chuck Sepers	Appleton Health Department	

Data Included

Appleton's CHA includes primary and secondary data. Primary data comes from a survey conducted by Appleton's Community Health Assessment Steering Committee. Secondary data is data available from other sources that is selected by staff of the Health Department.

Methodology

The Survey

The Steering Committee developed Appleton's Community Concerns Survey using a model from the Community Tool Box, created by the Center for Community Health and Development at the University of Kansas. The committee also reviewed similar surveys from the Fox Valley region and considered feedback from those efforts. The goal was to build on existing data—such as from the Mind Your Wellness and Imagine Fox Cities surveys—by asking more specific questions about the challenges and strengths experienced by people who live, work, and play in Appleton.

The survey was available from March 1 to August 31, 2024, both online and in paper form. It was open to anyone who lives, works, or spends time in Appleton. In total, 1,291 people responded, including 1,080 Appleton residents—about 84% of total responses.

To improve access, the survey was translated into the six most commonly spoken languages in the Appleton area, based on data from the Appleton Area School District. Those languages include: English, Spanish, Hmong, Kinyarwanda, Swahili, and Dari/Farsi. Paper copies in each language were made available at the Appleton Public Library. Translated versions were also shared directly with local organizations, such as Casa Hispana and the Hmong American Partnership. A special session at Long Cheng Market—where many Hmong elders and their families gather—helped elders complete the survey in Hmong.

In-person support sessions were also held at several community locations, including:

- Lawrence University
- Eagle Point Senior Living Community
- Oneida Heights (Appleton Housing Authority)
- City of Appleton's Citizen Academy
- Riverview Gardens (job training site)
- Salvation Army (during free lunch service)

At these sessions, participants could choose to complete the survey on paper or using an iPad—whichever was easier. In some cases, Health Department staff read the questions aloud and helped participants select their answers.

To increase awareness, the Health Department launched a social media campaign featuring local leaders sharing why participating in the Community Health Assessment matters. Posters and banners were also placed around Appleton in high-traffic areas like the Thompson Center (a senior activity center) and Appleton Park & Rec's Dance Studio (where parents often wait during children's programs).

Survey responses to statements were analyzed using a quadrant method, which looked at both how strongly people agreed with a statement and how important they believed it was. This two-part approach helped the committee identify which issues should be prioritized—especially those that were both widely agreed upon and considered highly important. For more details, see Appendix C.

Secondary data

The secondary data used in this Community Health Assessment (CHA) comes from a variety of trusted sources. Local data includes findings from projects such as Imagine Fox Cities, the Mind Your Wellness survey, the Appleton Police Department's Fall 2023 survey, and the Fox Cities Point-in-Time Count.

State and national data was gathered from reliable sources like the Wisconsin Department of Public Instruction, the U.S. Census, County Health Rankings, and United for ALICE (Asset Limited, Income Constrained, Employed), among others. For a full list of sources and links to more information, please see the References section.

Timeline

Steering Committee		
Choose / Ask Steering Committee	November 2023	Choose Community leaders with different backgrounds, workplaces, and topic-area focuses
Steering Committee Meetings	December 2023	Introductions, Hopes for the CHA Process
	December 2023	Discuss what data we already have (primary and secondary) along with what we want to learn using a survey
	January 2024	
	January 2024	
	March 2024	
	April 2024	
	November 2024	Shared Sense-Making
	July 2025	Finalize CHA Document

Survey		
Survey Live	March - August 2024	Online & In Person
Marketing of Survey	March 2024	News Segment with Interview on NBC 26
	March 2024	News Segment with Interview on WBAY
	April 2024	Banner & Surveys at Thompson Center
	April 2024	Banner & Surveys at Parks & Rec
	May 2024	Surveys at Catalpa
	May 2024	Surveys at Appleton Neighborhood Meeting
	May 2024	Surveys at Interagency Meeting
In-Person Survey Support	April 2024	at Eagle Point
	April 2024	at Oneida Heights
	April 2024	at City of Appleton's Citizen's Academy
	April 2024	at Lawrence
	April 2024	at Lawrence
	May 2024	at Riverview Gardens
	May 2024	at Salvation Army
Analyze Survey Data	August 2024 - January 2025	Appleton Health Department analyzes data from survey and secondary data

Final Document		
Write CHA	January - June 2025	Appleton Health Department writes final CHA document
CHA Approved by Board of Health	August 2025	Final CHA document is approved by Appleton Board of Health
CHA goes Public	August 2025	CHA is shared publicly online

Frameworks & Models

THE 10 ESSENTIAL PUBLIC HEALTH SERVICES

To protect and promote the health of all people in all communities

The 10 Essential Public Health Services provide a framework for public health to protect and promote the health of all people in all communities. To achieve equity, the Essential Public Health Services actively promote policies, systems, and overall community conditions that enable optimal health for all and seek to remove systemic and structural barriers that have resulted in health inequities. Such barriers include poverty, racism, gender discrimination, ableism, and other forms of oppression. Everyone should have a fair and just opportunity to achieve optimal health and well-being.



ESSENTIAL PUBLIC HEALTH SERVICE #1
Assess and monitor population health status, factors that influence health, and community needs and assets

ESSENTIAL PUBLIC HEALTH SERVICE #2
Investigate, diagnose, and address health problems and hazards affecting the population

ESSENTIAL PUBLIC HEALTH SERVICE #3
Communicate effectively to inform and educate people about health, factors that influence it, and how to improve it

ESSENTIAL PUBLIC HEALTH SERVICE #4
Strengthen, support, and mobilize communities and partnerships to improve health

ESSENTIAL PUBLIC HEALTH SERVICE #5
Create, champion, and implement policies, plans, and laws that impact health

ESSENTIAL PUBLIC HEALTH SERVICE #6
Utilize legal and regulatory actions designed to improve and protect the public's health

ESSENTIAL PUBLIC HEALTH SERVICE #7
Assure an effective system that enables equitable access to the individual services and care needed to be healthy

ESSENTIAL PUBLIC HEALTH SERVICE #8
Build and support a diverse and skilled public health workforce

ESSENTIAL PUBLIC HEALTH SERVICE #9
Improve and innovate public health functions through ongoing evaluation, research, and continuous quality improvement

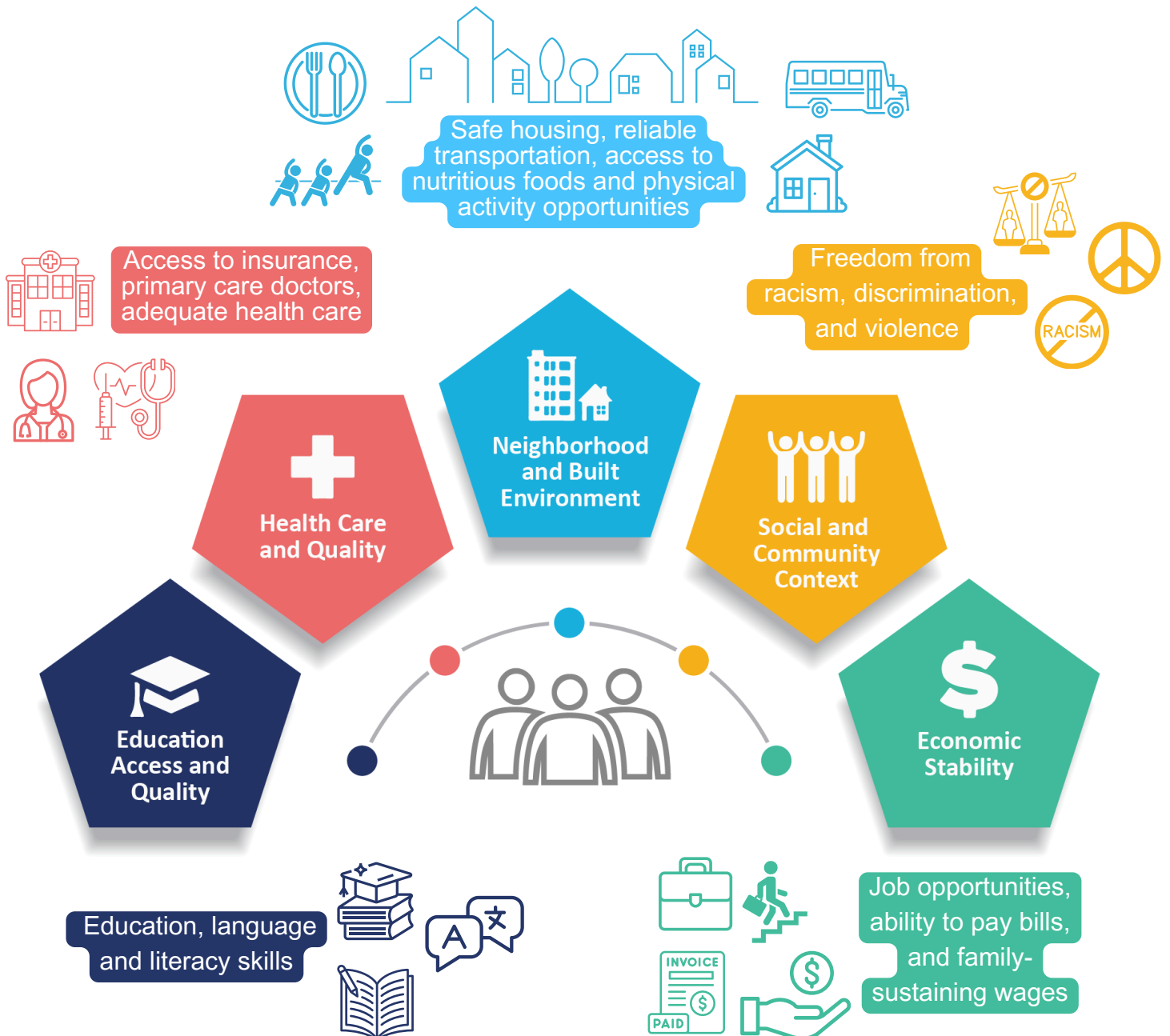
ESSENTIAL PUBLIC HEALTH SERVICE #10
Build and maintain a strong organizational infrastructure for public health

Frameworks & Models

Social Determinants of Health

Social Determinants of Health (SDOH) are the social and environmental conditions that influence health. They include the conditions in which people are born, grow, work, live, play, and age. SDOH also include the broader forces and systems that shape everyday life conditions. SDOH have a major impact on people's health, well-being, and quality of life.

These things contribute to the health & well-being of all people:



Frameworks & Models

Healthy People 2030

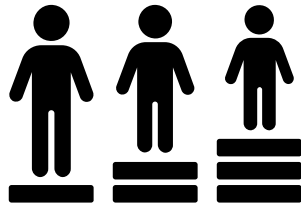
Healthy People 2030 sets data-driven national objectives to improve health and wellbeing over the next decade. It's part of the United States Department of Health and Human Services along with the Office of Disease Prevention and Health Promotion.

National Objectives to Improve Health & Wellbeing

Healthy People 2030 objectives help measure our nation's progress in critical areas of public health — and serve as a reliable data source to support organizations and individuals working to improve health and well-being for all.



Health Equity



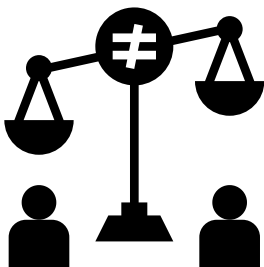
Prioritizing health equity means creating fair opportunities for everyone to achieve their best health. The National Association of County and City Health Officials (NACCHO) suggests using MAPP 2.0 as a framework for community health assessments and improvement plans. MAPP 2.0 stresses the importance of looking at “Mechanisms of Power” to better understand health equity.

Leading Health Indicators

Healthy People 2030 includes 23 Leading Health Indicators (LHIs), high-priority objectives that address major public health issues — from obesity to substance use to chronic disease prevention and more.



Health Disparities



Healthy People 2030 includes health disparities data for population-based core objectives with available demographic group data. Health disparities are differences in health that are closely linked to social determinants of health. Addressing health disparities is key to achieving health equity and realizing the Healthy People vision of improving the health and well-being of all.

Evidence-based Resources

Evidence-based resources (EBRs) are published reviews of intervention evaluations and studies to improve health. We've organized them into intuitive topics so you can easily find what you're looking for. Pick a topic you're interested in and explore relevant resources that can help you work to achieve Healthy People 2030 objectives.



Demographic Snapshot

CITY OF APPLETON TOTAL POPULATION 74,873



30,860
Number of
Households
Census Reporter

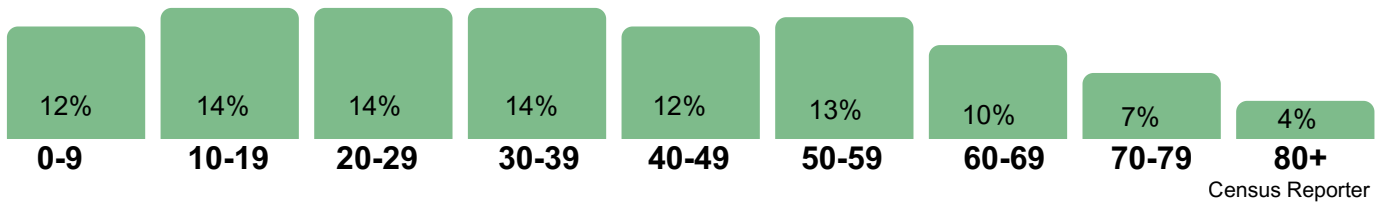


2.4
Persons per
Household
Census Reporter



36.9
Median age
Census Reporter

Population by Age Range



Gender



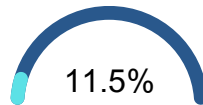
50%
Male



50%
Female

*too little data is collected on all other genders to report on
Census Reporter

Ability Status



of the population have a disability, including a hearing, vision, cognitive, ambulatory, self-care and independent difficulties
Census Reporter

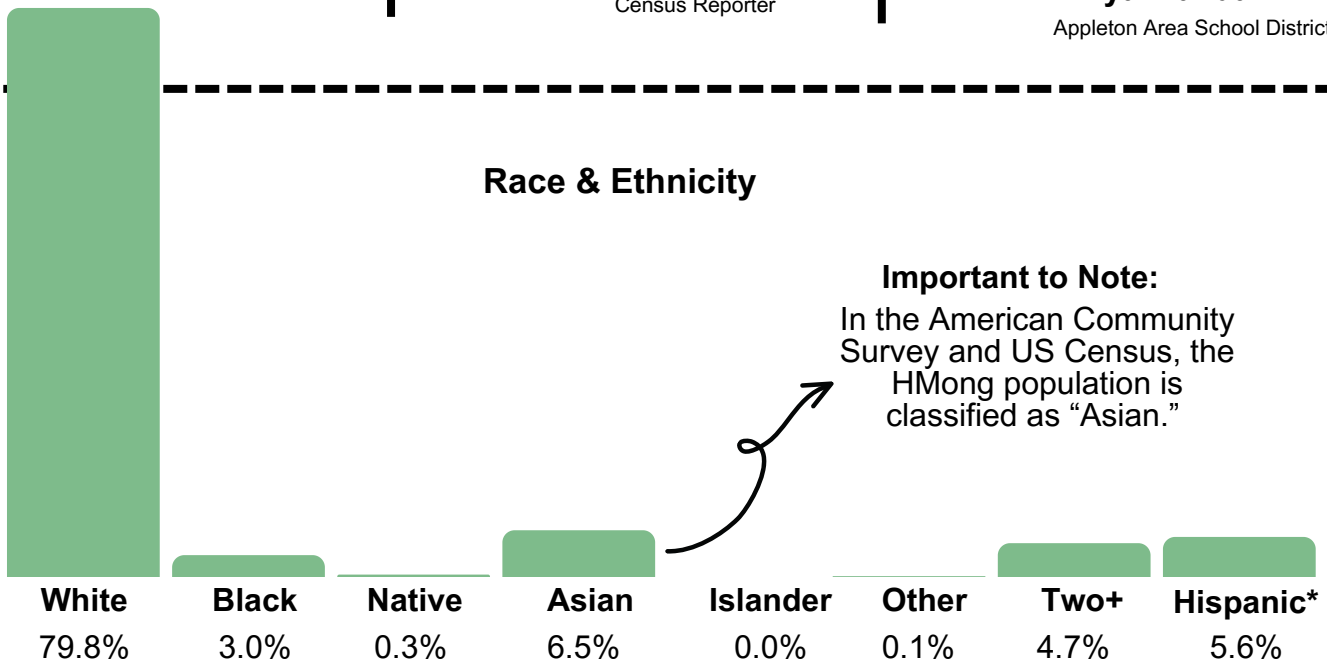
Languages



After **English**, the next most common primarily languages spoken in Appleton households are: **Spanish, HMong, Dari/Farsi, Swahili, and Kinyarwanda.**

Appleton Area School District (2024)

Race & Ethnicity



Important to Note:

In the American Community Survey and US Census, the HMong population is classified as "Asian."

*Hispanic includes respondents of any race. All other categories are non-Hispanic.
Census Reporter

Executive Summary

CITY OF APPLETON POPULATION: 74,873

Living in Appleton

Social Belonging in Appleton

\$77,450
Median Household
Income in Appleton

Over the past few years, **gender wage gaps are growing**

Public health promotes social connectedness to reduce isolation and create healthier, safer communities.

Is Living in Appleton Affordable?

Households making more than \$100,000/year believe living in Appleton is more affordable than those making less than \$100,000/year.



In 2024 in Appleton's three counties, **women are paid \$0.786 for every \$1.00 men are paid.**

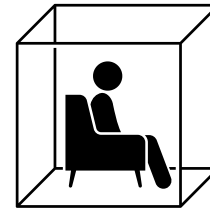
while **32%** of survey respondents reported **they are struggling**

only **59%** of Imagine Fox Cities' Well-Being survey respondents reported **they are thriving**

31,999
Number of Housing Units in Appleton

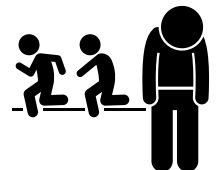
96%
Percentage of Housing Units in Appleton that are Occupied
Census Reporter

only **37%** of Community Concerns survey respondents **agree** that Appleton has **Safe & Affordable Housing Options**



"Social isolation can pose a health risk to people, even if they don't feel lonely."
CDC, Social Connectedness

20% of Community Concerns survey respondents **lack companionship**



one in four worry they may **run out of food** before they have money to buy more

Community Concerns Survey



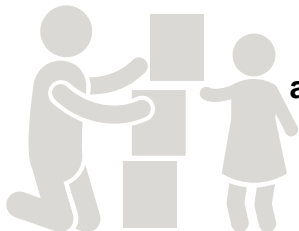
17% of Community Concerns survey respondents **feel isolated from others**

18% of Community Concerns survey respondents **feel left out**

The **cost of childcare** is increasing. In the past two years, families with two children in childcare in the Appleton area have been spending around 30% of their median household income on childcare costs.

Income Matters

When asked if **"Quality childcare is available and affordable"** only **31%** of Community Concerns survey respondents **Agreed**



Mind Your Wellness survey respondents reported that if they make **\$150,000 + a year** they are much more likely to **know how to access mental health care** than those who make less than \$150,000 a year



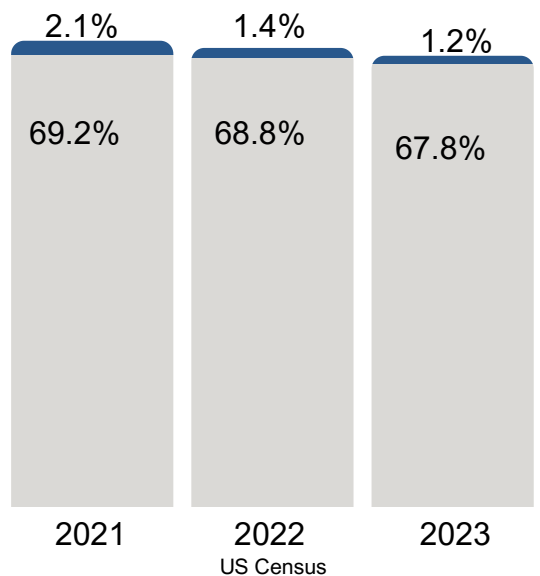
Economic Conditions

Employment

Meaningful Work

Meaningful work with a family-sustaining wage promotes financial stability, reducing stress and improving mental health while ensuring access to basic needs. Stable employment also supports overall community well-being by decreasing health disparities and fostering healthier lifestyles.

Percent of the population ages 16 and over that are in the labor force



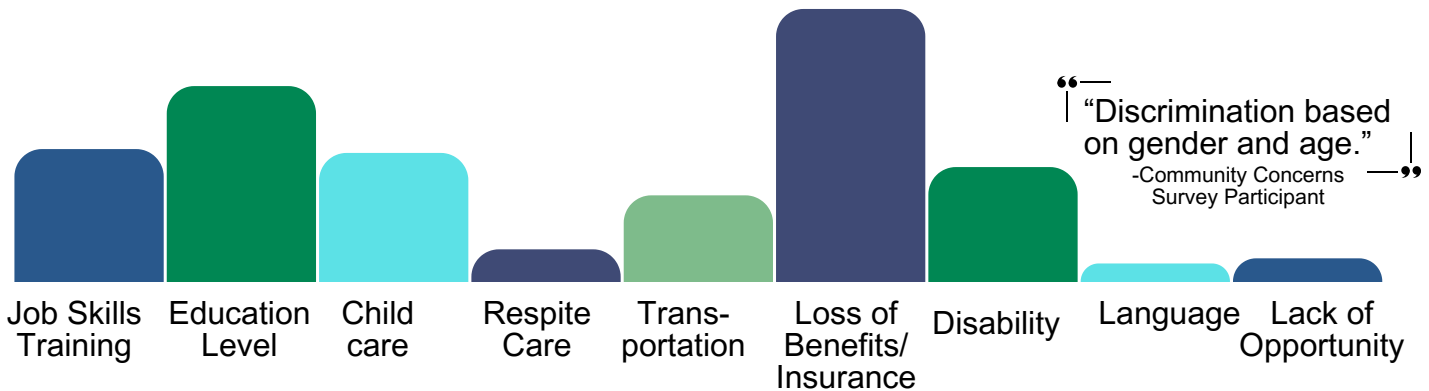
Labor Force
Unemployment

Family-Sustaining Wages

A family-sustaining wage is the income level necessary for a worker to meet their family's basic needs, including housing, food, healthcare, childcare, transportation, and other essential expenses, without relying on public assistance. It varies based on factors like family size, location, and cost of living.

According to Community Concerns Survey respondents, the following impact Appleton residents' ability to keep or move up in a job:

*The labor force includes civilians who are employed or unemployed but actively seeking employment, and members of the US Armed forces.



“Discrimination based on gender and age.”
-Community Concerns Survey Participant

“Medical debt and risk remove all possibilities of improving.”
-Community Concerns Survey Participant

“Health issues.”
-Community Concerns Survey Participant

“Small business cannot afford to provide benefits or salary increases.”
-Community Concerns Survey Participant

“There is no moving up in my job.”
-Community Concerns Survey Participant

“Work, life and family balance. Moving up in a position requires more time commitment to a job. The increase in responsibilities doesn't work well for my life and family right now.”
-Community Concerns Survey Participant

Economic Conditions

Annual Income

Higher Income is Associated with Better Health Outcomes

Higher income is associated with better health outcomes because it provides greater access to quality healthcare, nutritious food, safe housing, and educational opportunities. These promote overall well-being. Additionally, higher income reduces stress and financial strain, leading to healthier lifestyles and improved mental health.

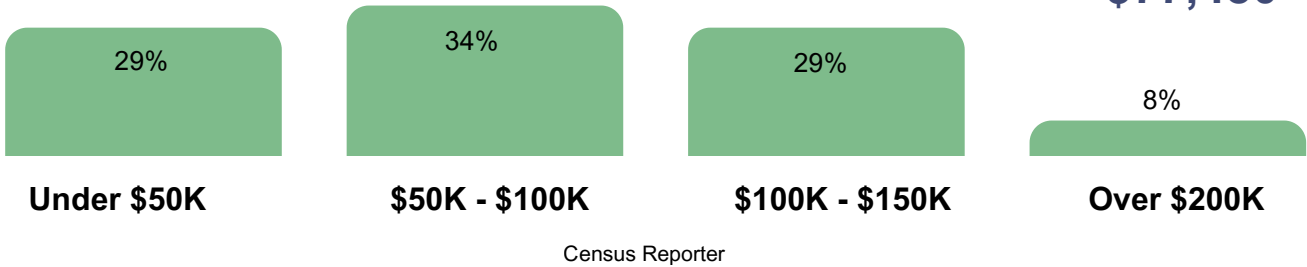
Per Capita Income
per person in Appleton:
\$48,093



Household Income

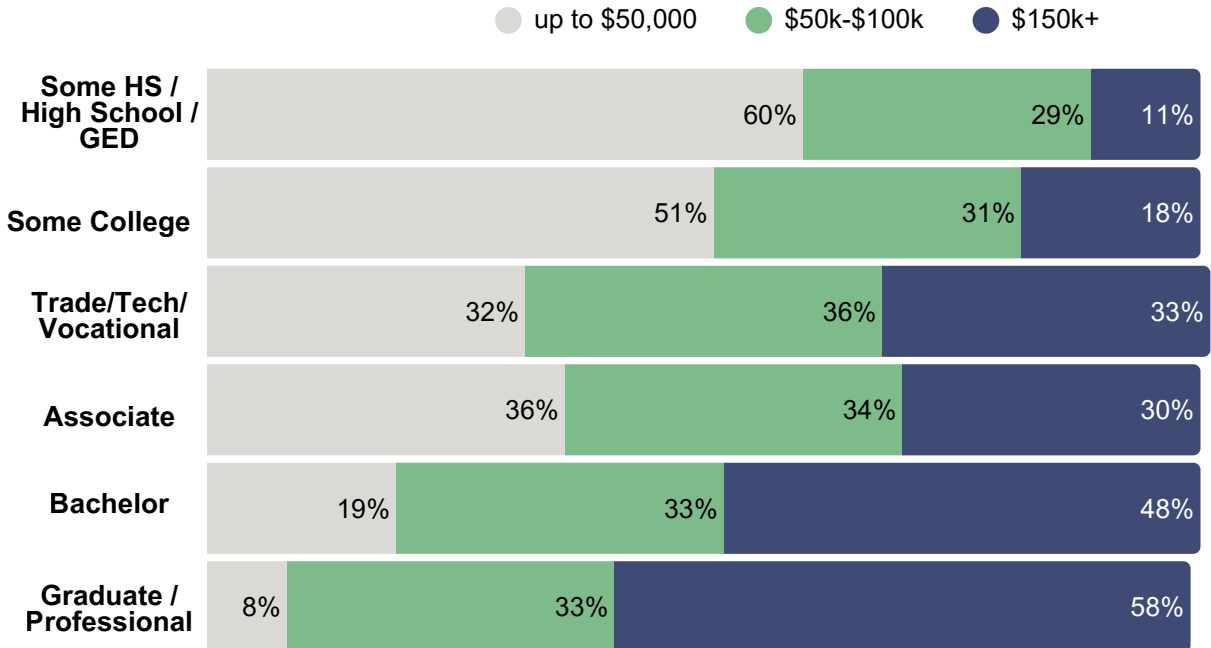


Median Household Income
in Appleton:
\$77,450



Household Income Based on Education

Higher levels of education are linked to better income opportunities, which can lead to improved health outcomes and greater access to resources that support well-being.



Community Concerns Survey

Economic Conditions

Income Disparities

Gender Wage Gaps in Appleton

The percentage of women's median earnings to men's median earnings for all full-time, year-round workers has continually decreased in the last three years.

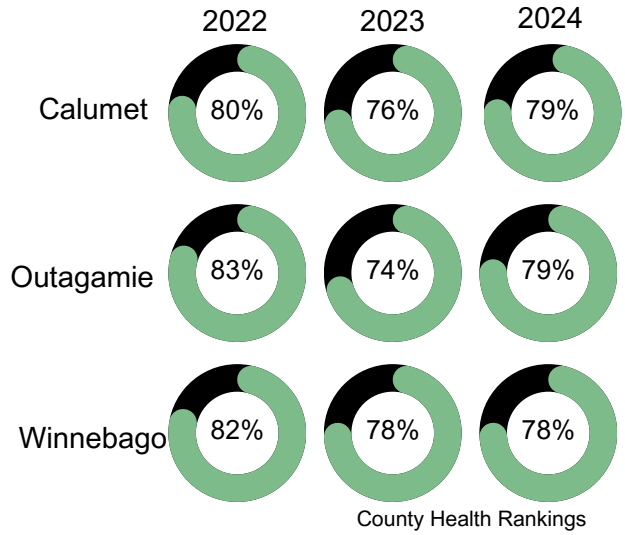
■ Women's Earnings
■ Men's Earnings

Over the past few years, **gender wage gaps are growing**, indicating a parallel growth in gender inequality.

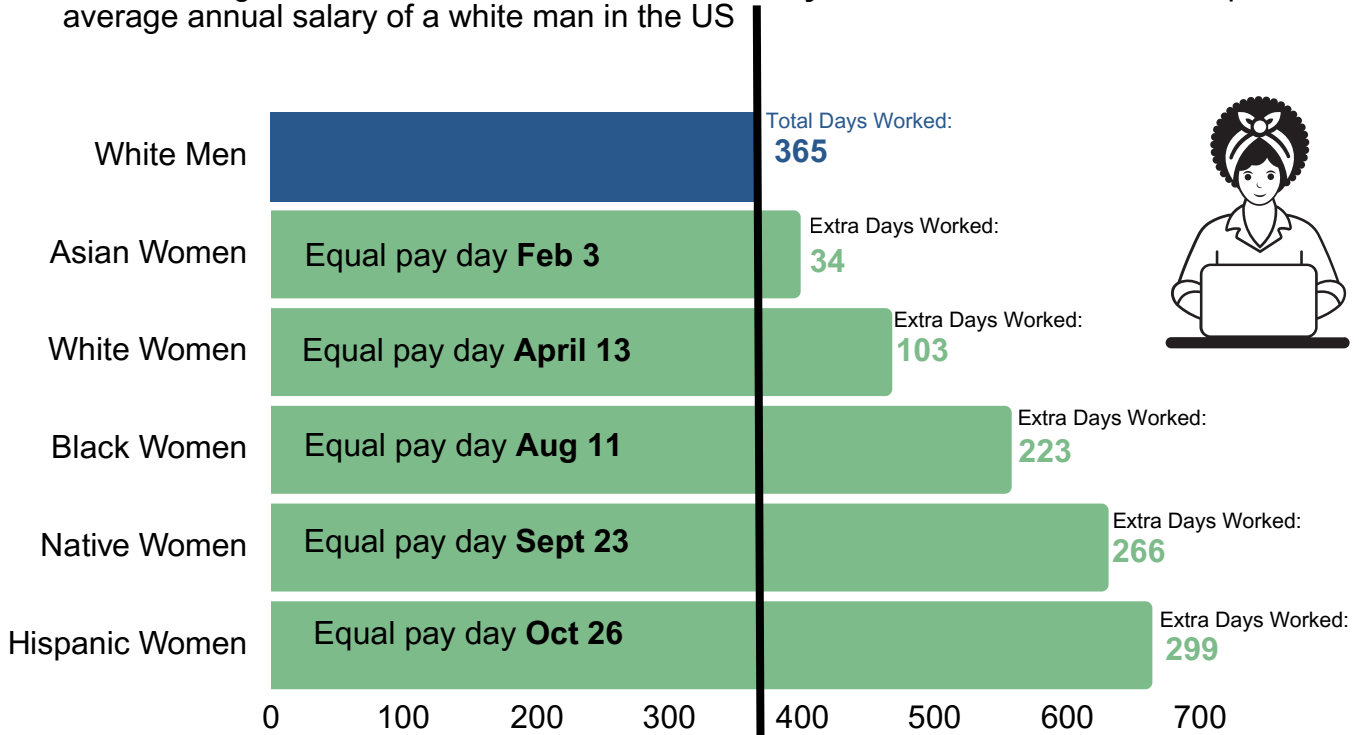


In 2024 in Appleton's three counties, **women are paid \$0.786 for every \$1.00 men are paid.**

County Health Rankings



The following demonstrates the **extra number of days a woman must work** to equal the average annual salary of a white man in the US



Women must work **months longer** to make the same amount white men make in one year

Economic Conditions

Factors Contributing to the Gender Pay Gap

Job Segregation

Women-dominated fields are lower-paid, even when they require the same level of skill, education, and training. These jobs are also less likely to offer benefits like paid time off, health insurance, and retirement plans.



Motherhood Penalty

Because caregiving responsibilities fall disproportionately on mothers, women are more likely to take time out of the workforce or scale back hours which can limit or postpone career advancement and corresponding pay increases.



Discrimination

Despite federal protections against workplace discrimination, LGBTQ+ people continue to experience bias and discrimination in all stages of employment.

AAUW: The Simple Truth Gender Pay Gap 2025

The earnings lost as a result of the pay gap have meant women have had **fewer opportunities to make ends meet**, let alone **save for emergencies or retirement**.



County Health Rankings: Findings & Insights on the Gender Pay Gap

Gender Pay Gap Health Outcomes

Opportunities

Lower incomes mean fewer opportunities to live in safe housing, buy nutritious food, and obtain quality education - all factors that contribute to health.



Physical Health

Gender pay inequities are associated with worse mortality outcomes, poorer self-rated health and increased disability.



Mental Health

Gender pay inequities lead to higher rates of stress, anxiety and depression.



Poverty

Closing the gender pay gap would reduce poverty among women, especially women of color, which would improve their long-term health..



An economist explains why women are paid less | World Economic Forum County Health Rankings: Findings & Insights on the Gender Pay Gap



Cost of Living

Cost of living is the amount of money needed to live a standard quality of life in a specific location at a specific time. That means that where you live, and year to year the cost of living can be very different. Cost of living usually takes into account, cost of shelter, transportation, food, utilities and healthcare.

US Dept of Labor: World Populations Review, Cost of Living Index by State

89%
of Appleton Community
Concerns Survey
respondents
can pay all their bills
every month

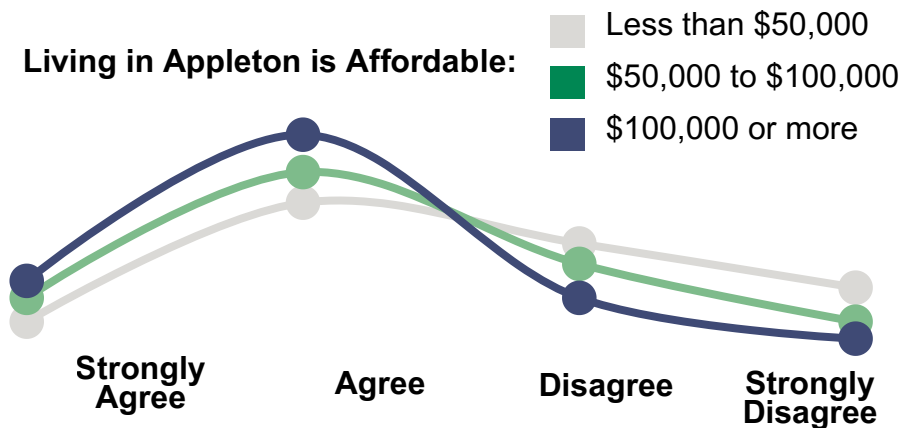
if they were suddenly without income
but → for one month, only
71%
would be able to cover all their
household expenses

Economic Conditions



Is Living in Appleton Affordable?

When asked if living in Appleton is affordable, survey responses indicate that households making more than \$100,000/year believe living in Appleton is more affordable than households making less than \$100,000/year.



“I feel Appleton is a great city to live in [but] I feel the expenses of living here are getting out of control. I’d hate to move out of the city but cheaper options will have to be considered if the prices keep going up (taxes, shell tax, etc) as my income doesn’t keep going up.”

Community Concerns Survey (percentages of survey responses based on income level)

Community Concerns Survey Participant

According to Community Concerns survey respondents,

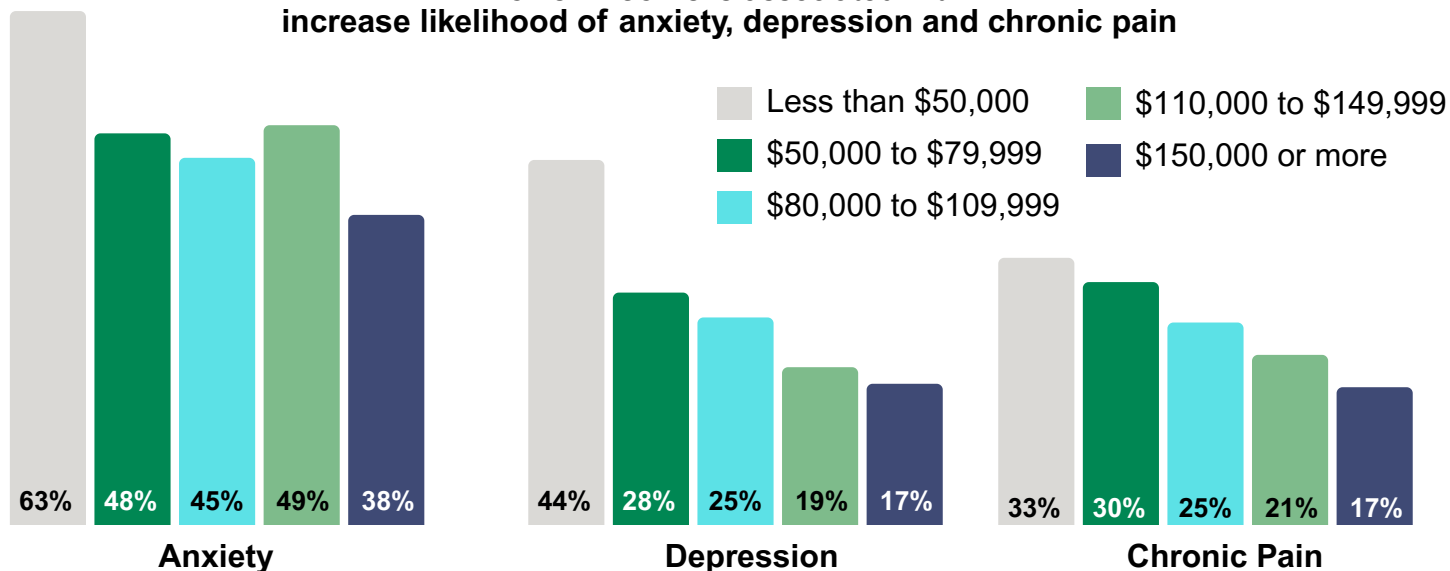
15% of Appleton households **struggle to pay for basic needs** such as: food, clothing, housing, transportation, childcare, etc.

Making Hard Choices

Financial strains and worries play significant roles in mental health. Worries about personal health and financial security are related to higher levels of psychological distress, anxiety and depression. This in turn has a negative impact on health behaviors and outcomes (heart disease, reduced immune response, mortality), as well as overall family well-being.

The Relationship Between Financial Worries and Psychological Distress Among US Adults, PMC

Lower income is associated with increase likelihood of anxiety, depression and chronic pain



Mind Your Wellness Survey

Economic Conditions

Financial Stress

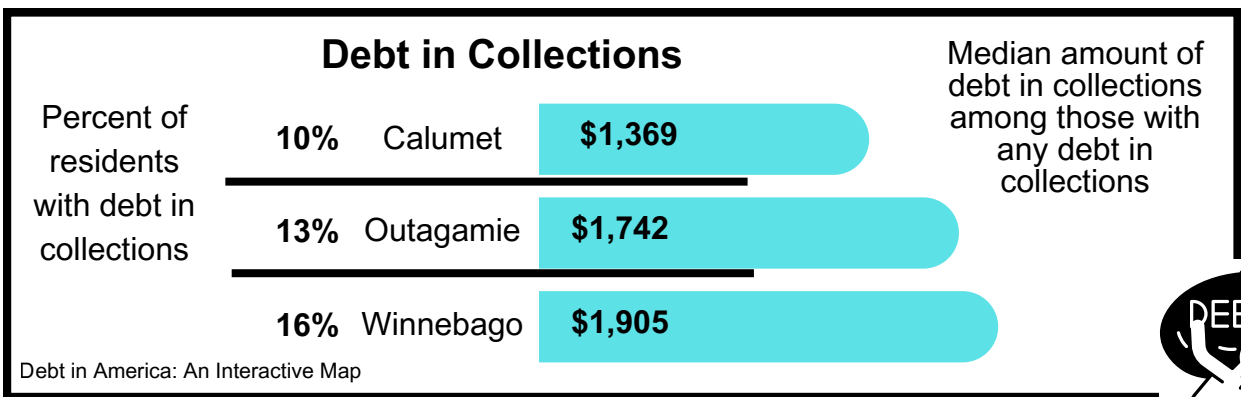
Financial stress can negatively impact overall health and well-being by increasing anxiety, depression, and chronic stress, which can contribute to high blood pressure, heart disease, and weakened immune function. It can also lead to poor health behaviors, such as unhealthy eating, lack of exercise, and delaying medical care due to cost concerns.

roughly
10%
of Appleton households have
zero or negative net worth

Propensity Score Card: Zero or Negative Net Worth

How Debt Affects Health

Debt can lead to chronic stress, which negatively impacts mental health and increases the risk of anxiety and depression. It can also cause people to delay or avoid necessary medical care due to financial strain. Over time, the constant pressure of debt can harm physical health, weaken social relationships, and reduce overall quality of life.



Persons Below Poverty Line

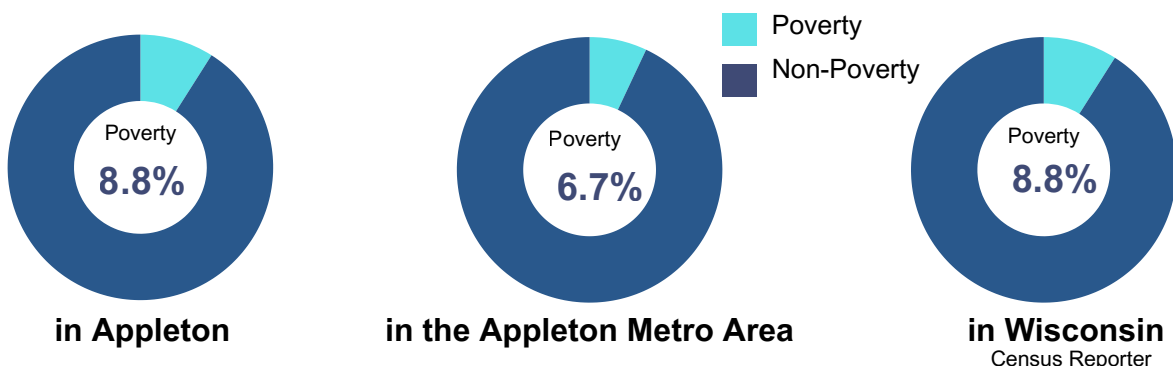
What is the poverty level?

Federal poverty levels are used to determine eligibility for certain programs and benefits, including savings on Marketplace health insurance, and Medicaid and Children's Health Insurance Program coverage.

HealthCare.gov Glossary: Federal Poverty Level

Persons below poverty level

In Appleton, 12% of children under the age of 18 years old are living under the poverty line. In Appleton 7% of seniors over the age of 65 are living under the poverty line.



Economic Conditions

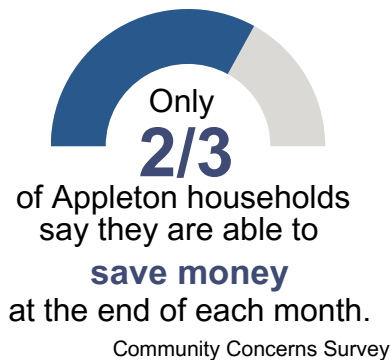
The Benefits Cliff

The “benefits cliff” represents the loss in benefits from public programs due to marginal increases in earned income. This loss may make the family worse off in terms of net resources despite the increase in earnings.

The benefits cliff mostly impacts individuals and households at or near the poverty level who are eligible for – but may not be receiving – multiple government programs. Recent research indicates that families with children often require an income up to three-and-a-half times the Federal Poverty Level in order to adequately cover the basic needs and living expenses for a family.



Quote from
https://uwcm.org/wp-content/uploads/2024/03/BENEFITS-CLIFF-STUDY-FINAL-7_24_20.pdf



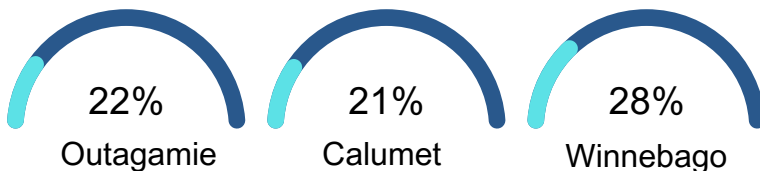
Did you know?
Minimum Wage is \$7.25/hour.

Persons Above Poverty Line but Struggling

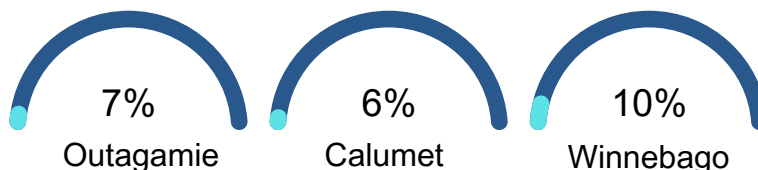
ALICE = Asset Limited Income Constrained Employed

The Asset Limited Income Constrained Employed (ALICE) threshold represents households that are above the poverty level, but do not have enough to afford the basics of housing, childcare, food, transportation, healthcare, and technology, plus taxes and a contingency fund (miscellaneous) equal to 10% of the household budget. These households are often called the “working poor,” referring to the fact that people in these households have jobs but still remain at or near the poverty level.

ALICE Households in 2023:



Households in poverty in 2023:



United for ALICE



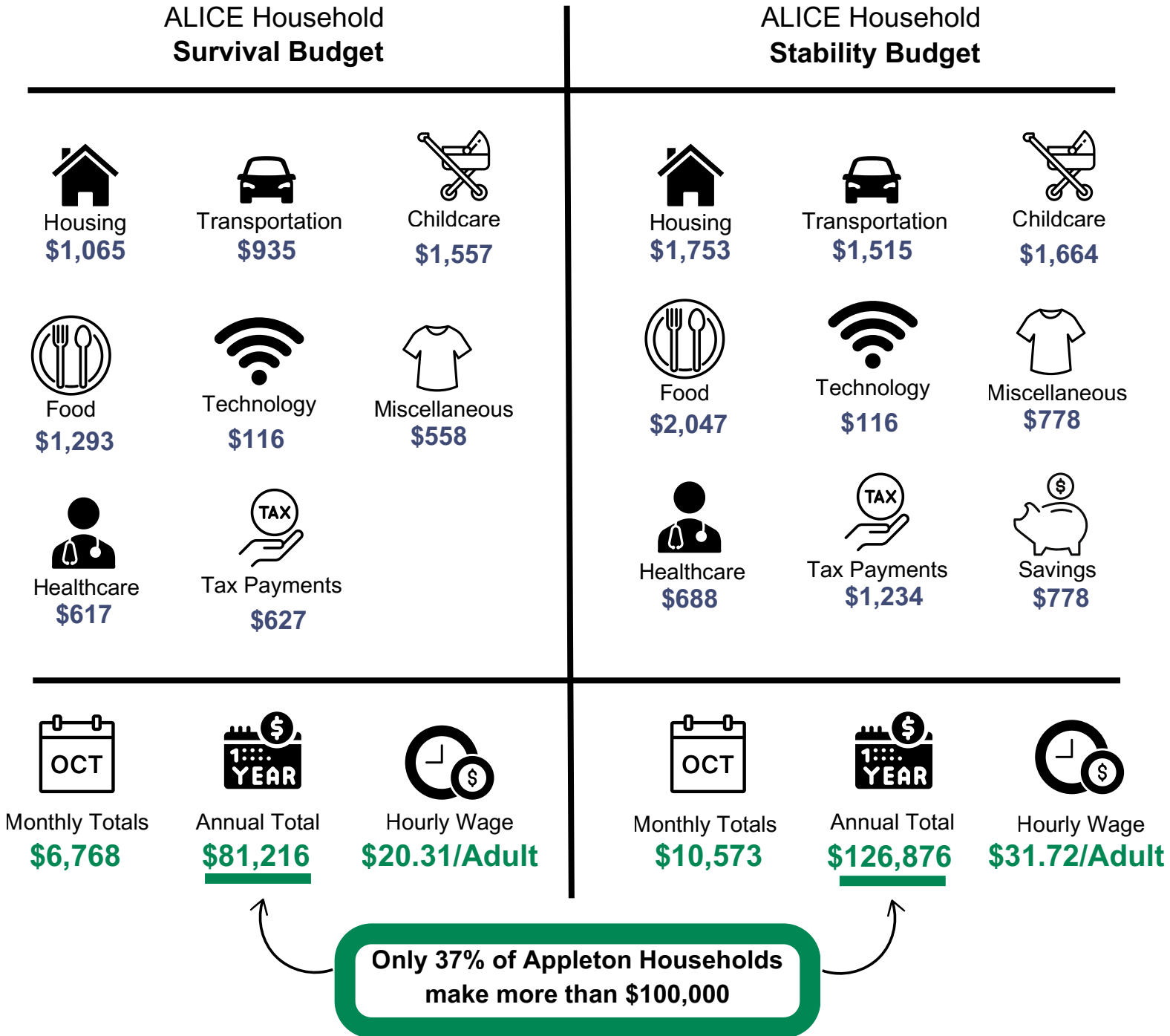
Living on a survival budget does **not** include savings for emergencies or future goals like college or retirement.

Economic Conditions

The ALICE (Asset Limited Income Constrained Employed) Threshold represents the minimum income level necessary for survival for a household. The following are the

Estimated monthly costs for a family of four living in Appleton

with two working adults and two children in childcare using data from 2023:



Data pulled from ALICE Household Survival Budget Calculator for 2 adults and two children (1 infant; 1 preschooler) using Outagamie, Calumet & Winnebago counties.

Household Survival Budget Calculator for Wisconsin in 2023, United for ALICE;
Household Stability Budget Calculator for Wisconsin in 2023, United for ALICE

Neighborhood & Built Environment



Impact of Housing on Health & Wellbeing

Safe, affordable, and adequate housing is essential for health and well-being because it provides stability, security, and a healthy environment for individuals and families. Additionally, stable housing promotes mental health by reducing stress and anxiety associated with housing insecurity or homelessness. By ensuring access to quality housing, communities can support healthier lifestyles, improve social and economic stability, and reduce health disparities.

Safe Housing: Environmental Factors

Radon, a naturally occurring gas that is radioactive and can cause lung cancer, is present in the Appleton area. The goal is that every home in Appleton has been tested for radon and has a mitigation system if warranted. The local county health departments provide radon testing kits for as little as \$5 a kit.



Safe

Safe housing is a stable, structurally sound living environment that protects residents from hazards such as violence, toxins, extreme weather, and health risks while ensuring access to essential utilities and sanitation.

and

Affordable

Affordable housing is housing that costs no more than 30% of a household's income.

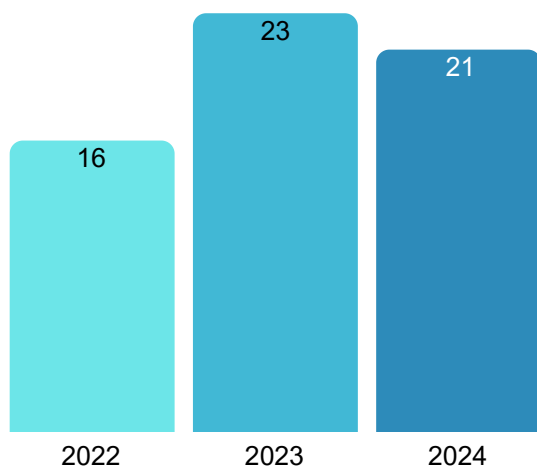
and

Adequate

Adequate housing meets the needs of the family who occupies it, having sufficient space to prevent overcrowding, clean water and sanitation, is accessible for all household members, and is proximal to essential services like jobs, school, healthcare, and transportation.

Blood Lead Poisoning

The current definition of blood lead poisoning (elevated levels) is 3.5 micrograms per deciliter. In 2022, the definition was at 5.0 micrograms per deciliter. The following cases are all blood venous levels only for children ages 5 and under:



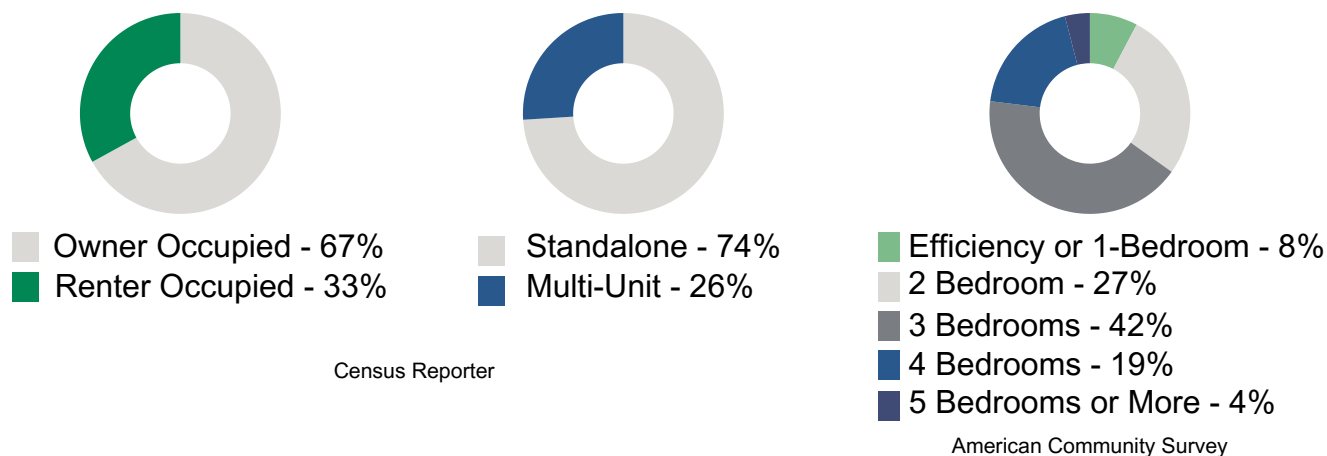
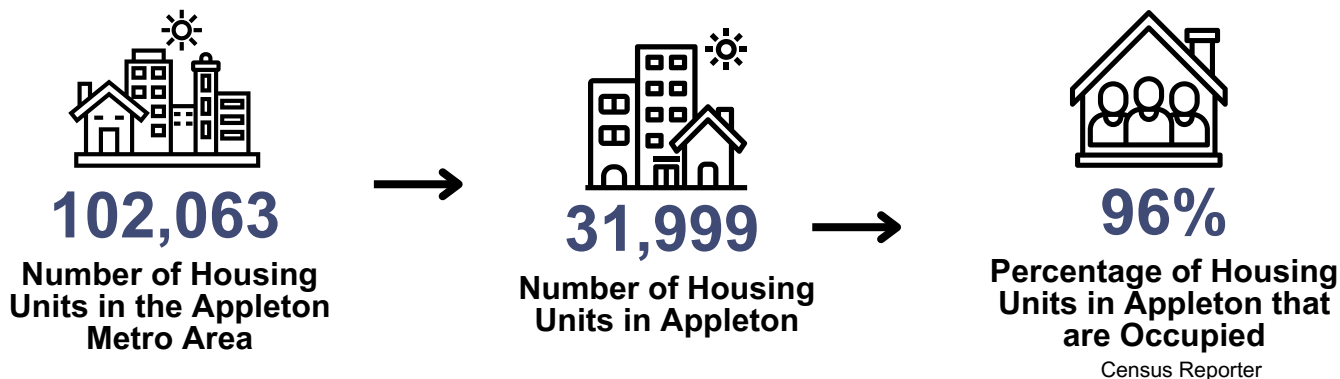
2022 2023 2024
City of Appleton's Health Department's Annual Reports

Neighborhood & Built Environment

Units & Occupancy

A market study completed by the City of Appleton's Housing Task Force (2022) demonstrated that the City would "need to deliver approximately 3,000 housing units between 2020 and 2030, or approximately 300 units annually, to accommodate the current needs of the community and its projected future growth."

City of Appleton's Housing Development Policy Guide, 2024



Barriers to Renting

Barriers that keep people from being able to rent:

- Prior Evictions
- Poor Credit History
- High Costs of Housing and Low Wages
- Raising Costs of Housing and Fixed Incomes
- Lack of Enough Affordable Housing
- Lack of Enough Supportive Housing Programs
- Long Waitlists for Apartments and Supportive Housing Units
- Complex Requirements or Processes to enter Apartments or Supportive Housing Units
- Locational Challenges (specifically related to Transportation Issues or School District Needs)
- Demand for Accessible Housing is higher than the Current Quantity
- Language Barriers



Did you know?

In Wisconsin, evictions can stay on record with the courts for twenty years, which can be used by landlords to deny rental applications.

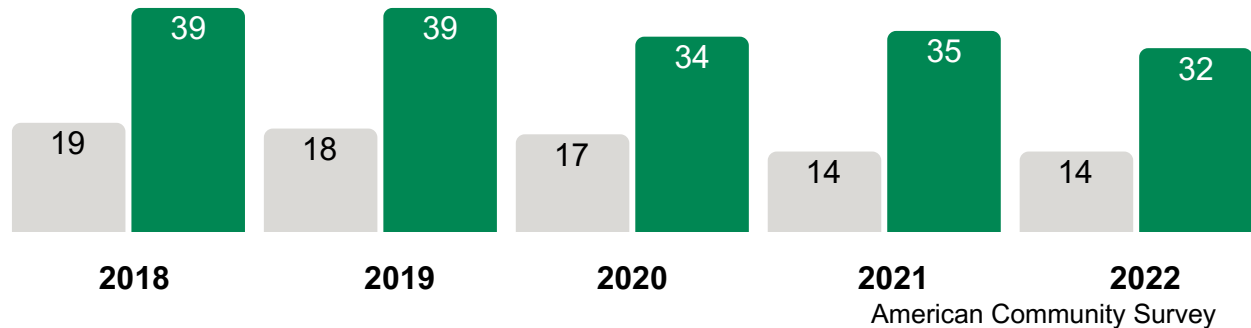
Wisconsin Watch

Neighborhood & Built Environment

Housing Cost Burden

The following demonstrates the percentage of households in Appleton who have housing costs greater than or equal to 30 percent of their monthly income.

Owner Occupied
 Renter Occupied



“As I am about to turn 77, I have many concerns regarding affordable and senior living, meaning less than \$1000 a month!”
 -Community Concerns Survey Participant

“As a person with good credit, no criminal record, and a secure job, it was very difficult to find housing as a single parent. When I rented, I had no money to save at all.”
 -Community Concerns Survey Participant

“I have many friends of various ages who qualify for low or moderate income housing. Wait lists are way too long. If we didn’t own our condo, paying the very high “market rate” housing of the newer apartments downtown would threaten our future finances.”
 -Community Concerns Survey Participant

“Housing costs in the Fox Valley as a whole are increasing at an alarming rate. These costs are quickly turning two income households into two plus income households to comfortably afford basic lifestyles.”
 -Community Concerns Survey Participant

“Too expensive to rent and if you don’t have a perfect credit you can’t buy a house either.”
 -Community Concerns Survey Participant



“My rent is 80% of my income.”
 -Community Concerns Survey Participant

only **37%** of Community Concerns survey respondents agree that Appleton has **Safe & Affordable Housing Options**

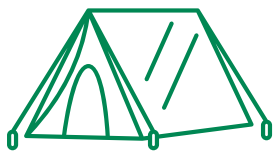


“I am 70 years old and still working to be able to afford my apartment and expenses.”
 -Community Concerns Survey Participant

Neighborhood & Built Environment

Homelessness

What Consists of “Homelessness”?



Living in an “uninhabitable” place like an **abandoned building or outside in a car, a tent, under a bridge, in the woods, in a park**, etc. The PIT Count captures the number of individuals living like this twice a year.



Temporarily staying in a **hotel, hospital, jail, “couch-surfing,” doubled-up, staying with family or friends**, etc. and having nowhere stable to go after. It is unknown how many people in Appleton are living this way.



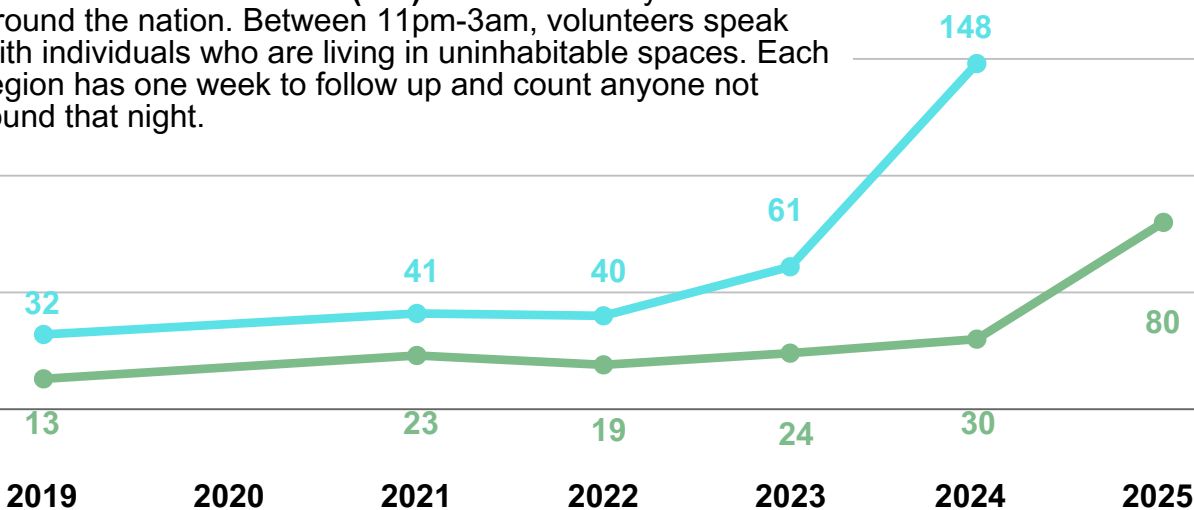
Appleton has two **emergency shelters** (Pillars Adult Shelter and Pillars Adult/Family Shelter) and one **domestic violence shelter** (Harbor House)

The Fox Cities is seeing an increase of those seeking resources to address basic needs.

Fox Cities Point in Time Count

● Winter ● Summer

The **Point in Time Count (PIT)** occurs twice a year in cities around the nation. Between 11pm-3am, volunteers speak with individuals who are living in uninhabitable spaces. Each region has one week to follow up and count anyone not found that night.



Fox Cities Point in Time Count data

Neighborhood & Built Environment

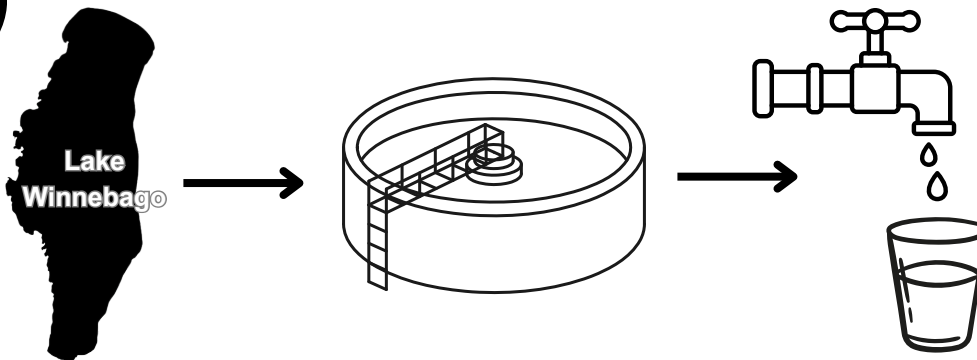
Physical Environment

Did you know?

The source of Appleton's drinking water is Lake Winnebago. Lake Winnebago is in the Fox and Wolf River watersheds.

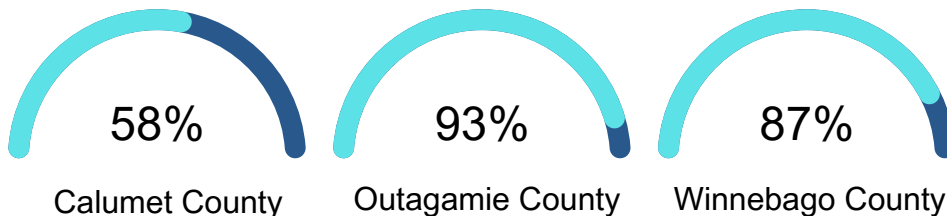
Drinking Water

The Appleton Water Treatment Facility treats Lake Winnebago water with a multiple-step process that deactivates and destroys illness-causing microorganisms while removing other contaminants.



The water is lime softened and filtered through granular activated carbon for turbidity removal. Ultraviolet Light is used as a disinfection process for Cryptosporidium. Fluoride is added for dental health. Finally, chlorine disinfection provides safe, drinking water throughout the distribution system and to your faucets.

Public Water Supplies with Fluoride Content in 2022



Wisconsin Environmental Public Health Tracking Program

Why fluoride?

Fluoride reduces cavities

Fluoride

The CDC named **fluoridation of drinking water one of 10 great public health interventions of the 20th century** because of the dramatic decline in cavities since community water fluoridation started in 1945. According to the CDC, community water fluoridation is a cornerstone strategy for prevention of cavities in the U.S. It is a practical, cost-

effective, and equitable way for communities to improve their residents' oral health regardless of age, education, or income.

<https://www.cdc.gov/fluoridation/about/index.html>

Neighborhood & Built Environment

Transportation

Car Ownership

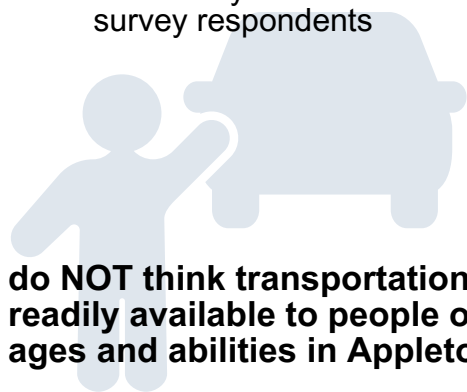
The majority of people in Appleton use a personal vehicle to commute to work, along with doing everyday errands. However, locally, state-wide and nationally, the percentage of workers who commute via personal vehicle has declined over the past five years. This is likely due to the increase in virtual working options.

“This is a must-have car place.”

-Community Concerns survey participant

1 in 4

Community Concerns survey respondents



do NOT think transportation is readily available to people of all ages and abilities in Appleton.

only **91%**

of renters in Appleton have access to a vehicle

compared to **99%**

of homeowners in Appleton have access to a vehicle



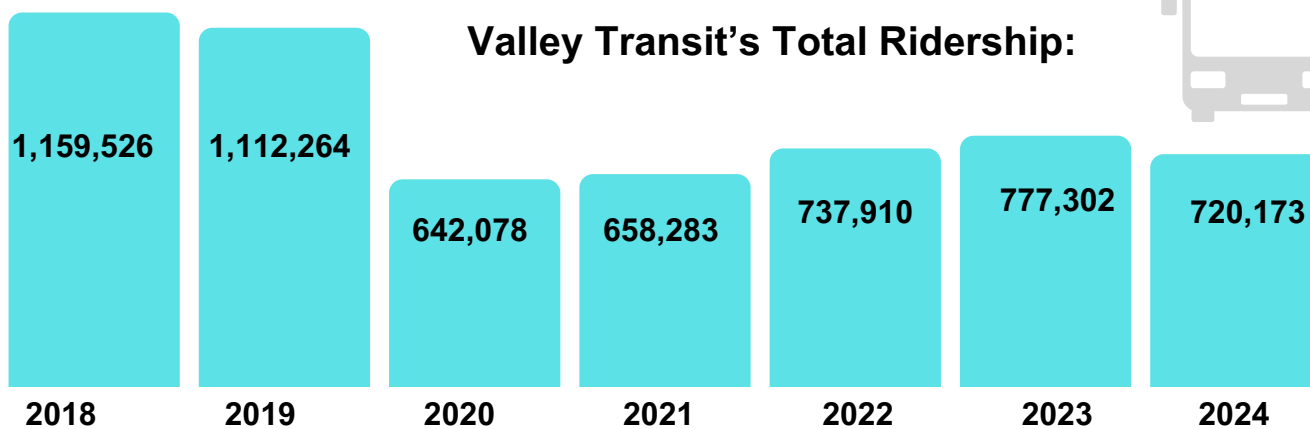
American Community Survey

Public Transportation

Valley Transit partners with 9 municipalities, 3 counties and many other entities to provide diverse transportation services across the Fox Cities area. There are 18 routes. In addition, the **VT Connector** is a fully accessible shared-ride van service designed to supplement Valley Transit’s bus service. In the past few years, Valley Transit has struggled to fill bus driver positions, which has led to a decrease in bus times and routes.



Valley Transit’s Total Ridership:



Valley Transit Annual Fact Sheets

“Public transportation is woeful. We need a massive investment in buses and trains.”

-Community Concerns survey participant

Neighborhood & Built Environment

Pedestrian Traffic



“Some of the sidewalks are uneven; I use a walker and the sidewalks sometimes can be a hazard for me.”

-Community Concerns survey participant



8 out of 10

Community Concerns survey respondents



think Appleton is bikeable, walkable, and/or wheelable.

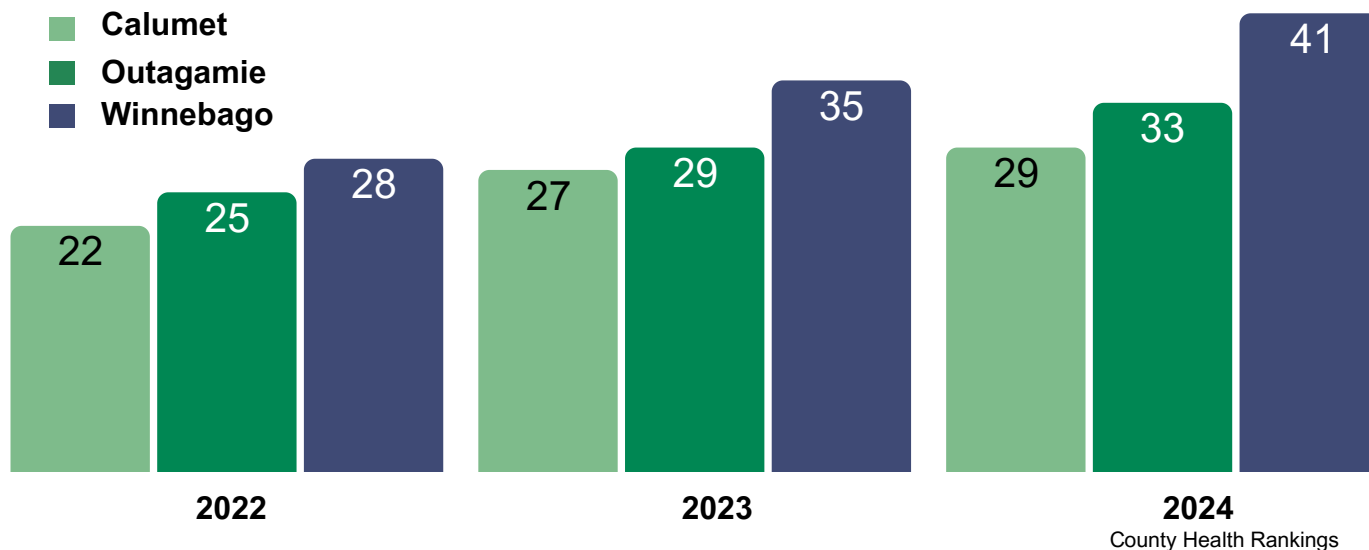
Childcare Expenses

The cost of childcare is increasing. In the past two years, families with two children in childcare in the Appleton area have been spending around 30% of their median household income on childcare costs.



Childcare Cost Burdens

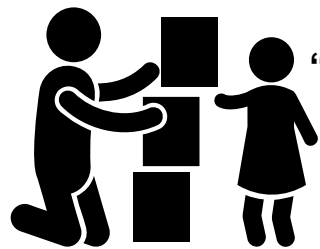
This represents the percentage of a family’s median household income they are spending on childcare costs for two children.



“Childcare prices are out of control. My kids only go to a daycare center two days a week because it’s all we can afford and it’s \$304 a week, which is outrageous. My husband and I both have good paying jobs (over \$30/hour) but we still struggle to make ends meet because of the prices of childcare and inflation. My husband went down to working four days a week because it was more cost effective for him to work one day less a week than us adding a third day of daycare per week.”

-Community Concerns survey participant

Education Access & Quality



When asked if
“Quality childcare is available and affordable”
only **31%**
of Community Concerns survey respondents
Agreed



Quality Education

Quality education, in the context of public health, means that everyone has access to a safe and supportive learning environment, skilled teachers, and the resources they need to develop knowledge and skills for a healthy life. It helps people make informed choices about their health, find good jobs, and contribute to their communities, leading to better overall well-being.

Here are key factors that impact the quality of education:



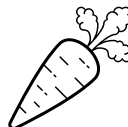
Funding & Resources

Schools need proper funding for books, technology, safe buildings, and learning materials.



Curriculum & Teaching Methods

Up-to-date, engaging, and culturally relevant teaching improves education quality.



Student Health & Nutrition

Healthy students (physically and mentally) learn better.



Technology & Internet Access

Digital tools and internet access expand learning opportunities.



Qualified Teachers

Well-trained, motivated teachers improve student learning outcomes.



Safe & Inclusive Environment

Schools should be free from violence, discrimination, and bullying.



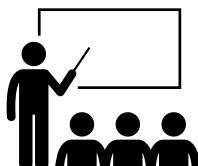
Family & Community Support

Parental involvement and community programs enhance learning.



Access to Early Childhood Education

Strong early learning experiences set the foundation for future success.



Class Size

Smaller classes allow more individual attention and better learning experiences.



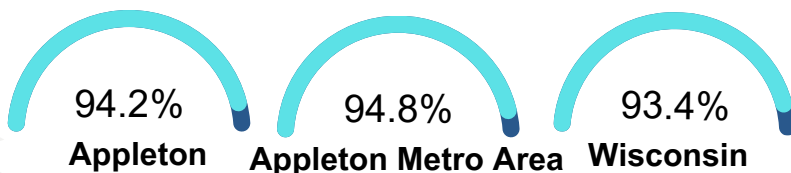
Education Policies & Leadership

Strong policies and leadership ensure high standards and continuous improvement.

Education Access & Quality

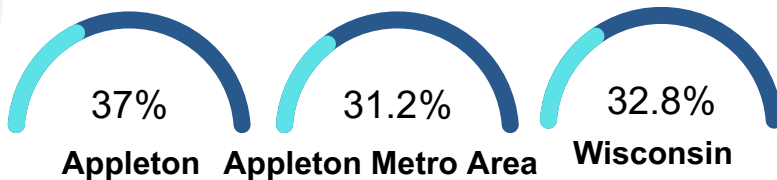
Educational Attainment

High School Graduate or higher



*Population 25 years and over; Census Reporter 2023

Bachelor's degree or higher



*Population 25 years and over; Census Reporter 2023

Local opportunities for higher education in the Appleton area include:



Opportunity Gaps

Opportunity gaps in education refer to the unequal access to resources, support, and conditions needed for students to succeed in school. These gaps are often influenced by social determinants of health, such as income, race, neighborhood, and family circumstances.

Consider this

According to the Community Concerns Survey:



Adult Literacy

The following are estimated percentages of adults (ages 16 to 74 years old) with literacy scores of 1, 2, or 3. Those with level 1 literacy are at risk for facing difficulties using or comprehending print material. Those with level 2 literacy can be considered nearing proficiency, but may still struggle to perform complex inferencing and evaluation tasks. Those with level 3 or higher are considered to be proficient with working with information and ideas in text.

● Under Level 1 ● Under Level 2 ● Under Level 3



National Center for Education Statistics

Social & Community Context

Social Connectedness

What is Social Connectedness?

Social connectedness is vital for public health because it improves mental and physical well-being, reduces stress, and encourages healthier behaviors. Strong relationships and supportive communities lead to better health outcomes, faster recovery from illness, and greater resilience in times of crisis. Public health promotes social connectedness to reduce isolation and create healthier, safer communities.

74%

of Community Concerns survey respondents **feel connected to others in their community**



57%
agree

43%
disagree



People in the community have adequate emotional & social support

Community Concerns Survey

Feeling Supported

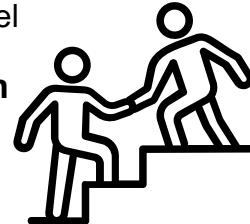


86%

of Community Concerns survey participants **have friends or family who could help them any time of day or night if they needed help**

75%

of Community Concerns survey participants feel their community **supports them in obtaining their health goals**



Having a Community



32%
percent of

residents age 65 and older who live alone
(not including those living in group homes such as nursing homes)
Fox Valley Data Exchange

Belonging

Belonging refers to the sense of being accepted, valued, and connected within a community or social group. It is a key social determinant of health, influencing mental well-being, stress levels, and overall health outcomes.



83%

of Community Concerns survey participants **feel they belong in their community**

"I see social connection as an urgent public health need in our community."

-Community Concerns Survey Participant

Social & Community Context

Social Vulnerability Index

The Social Vulnerability Index (SVI) value indicates the relative vulnerability of every U.S. Census tract by ranking tracts on 16 social factors. The SVI value is a percentile rank (ranging from 0 to 1), with higher values indicating greater vulnerability. For example, an SVI rank of 0.85 indicates that 85% of tracts in the nation experience social vulnerability equal to or lower than the tract of interest.

2022 National Overall SVI Scores:

0.0115

LOW

Calumet

0.1549

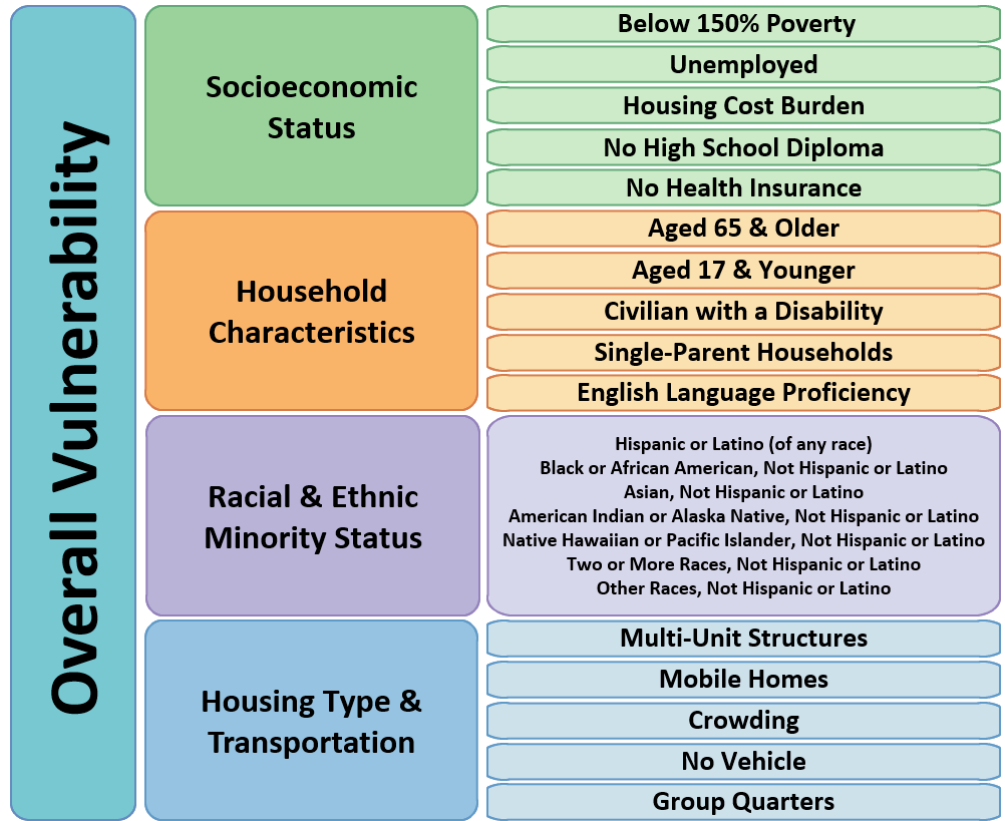
LOW

Winnebago

0.0671

LOW

Outagamie



CDC, Social Vulnerability Index

in Appleton's Community Concerns Survey,

94%

of survey respondents enjoy a good quality of life



but in Imagine Fox Cities' Well-Being survey, issued only a few years before in 2021, only

52%

of survey respondents reported they are thriving

while

45%

of survey respondents reported they are struggling



and

3%

of survey respondents reported they are suffering

Social & Community Context

Isolation & Loneliness

Social isolation is when a person does not have relationships or contact with others and has little to no social support.

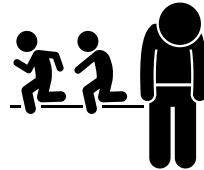
CDC Social Connectedness



17%

of Community Concerns survey respondents

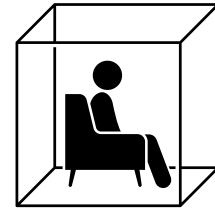
feel isolated from others



18%

of Community Concerns survey respondents

feel left out



20%

of Community Concerns survey respondents

lack companionship

the Mind Your Wellness Survey reported that people who report **always feeling isolated are:**

- **More likely** to be experiencing chronic pain
- **More likely** to have income less than \$150,000 annually
- **49 times more likely** to have symptoms of anxiety
- **17 times more likely** to have symptoms of depression
- **Less likely** to have children

“Social isolation can pose a health risk to people, even if they don’t feel lonely.”

CDC, Social Connectedness

Loneliness is feeling alone or disconnected from others. It is feeling like you do not have meaningful or close relationships or a sense of belonging. It reflects the difference between a person's actual and desired level of connection.

CDC Social Connectedness

lack of social & emotional support



About

1 in 4

adults in the U.S.

CDC Social Connectedness



About

1 in 3

adults in the U.S.

feel lonely

“Even a person with a lot of friends can feel lonely.”

CDC, Social Connectedness

Did you know?



Loneliness and social isolation may be shaped by conditions in the environments where people are born, live, work, learn, worship, and play. These conditions can affect the ability to connect socially. For example, the availability of resources that exist in a community, such as parks, libraries, public transportation, and programs, support the development of social connection.

CDC, Social Connectedness

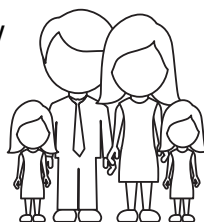
Social & Community Context

Economic Cost of Social Connectedness

Social disconnectedness increases healthcare costs due to higher rates of mental illness, chronic disease, and premature mortality. It also reduces workplace productivity and economic growth as isolated individuals are more likely to experience stress, absenteeism, and unemployment. These factors create a significant financial burden on healthcare systems, businesses, and society as a whole.

“Many of the events are family-focused with narrow definition of what ‘family’ is: all related by blood, straight, with two kids.”

-Imagine Fox Cities Participant



“We need more affordable/free cultural events that aren’t drunk fests.”

-Imagine Fox Cities Participant



“The quality of life is lowering as the wealth gap increases between community members.”

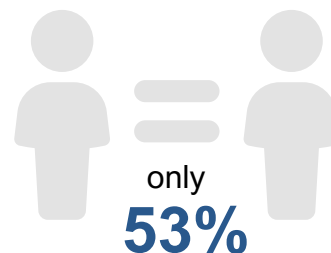


“You can’t enjoy all of Appleton when you can’t afford to participate.... It’s not inflation it’s profit over people and incredibly obvious. That’s what causes frustration and issues with feeling fulfilled.”

-Community Concerns Survey participants

Discrimination

Discrimination has serious consequences for a person’s overall health and well-being, affecting both physical and mental health. Chronic exposure to discrimination increases stress, leading to higher risks of anxiety, depression, and even post-traumatic stress disorder (PTSD). Physically, prolonged stress can contribute to conditions like high blood pressure, heart disease, and weakened immune function. Discrimination also creates barriers to healthcare, as individuals may avoid seeking medical treatment due to fear of mistreatment or receive lower-quality care due to bias in the healthcare system. Socially and economically, discrimination limits access to education, job opportunities, and financial stability, which in turn affects long-term well-being.



of Community Concerns survey participants **believe people are treated fairly and without discrimination** in Appleton

Health Disparities by Race

Comparison of Individuals who Feel Rested When Waking



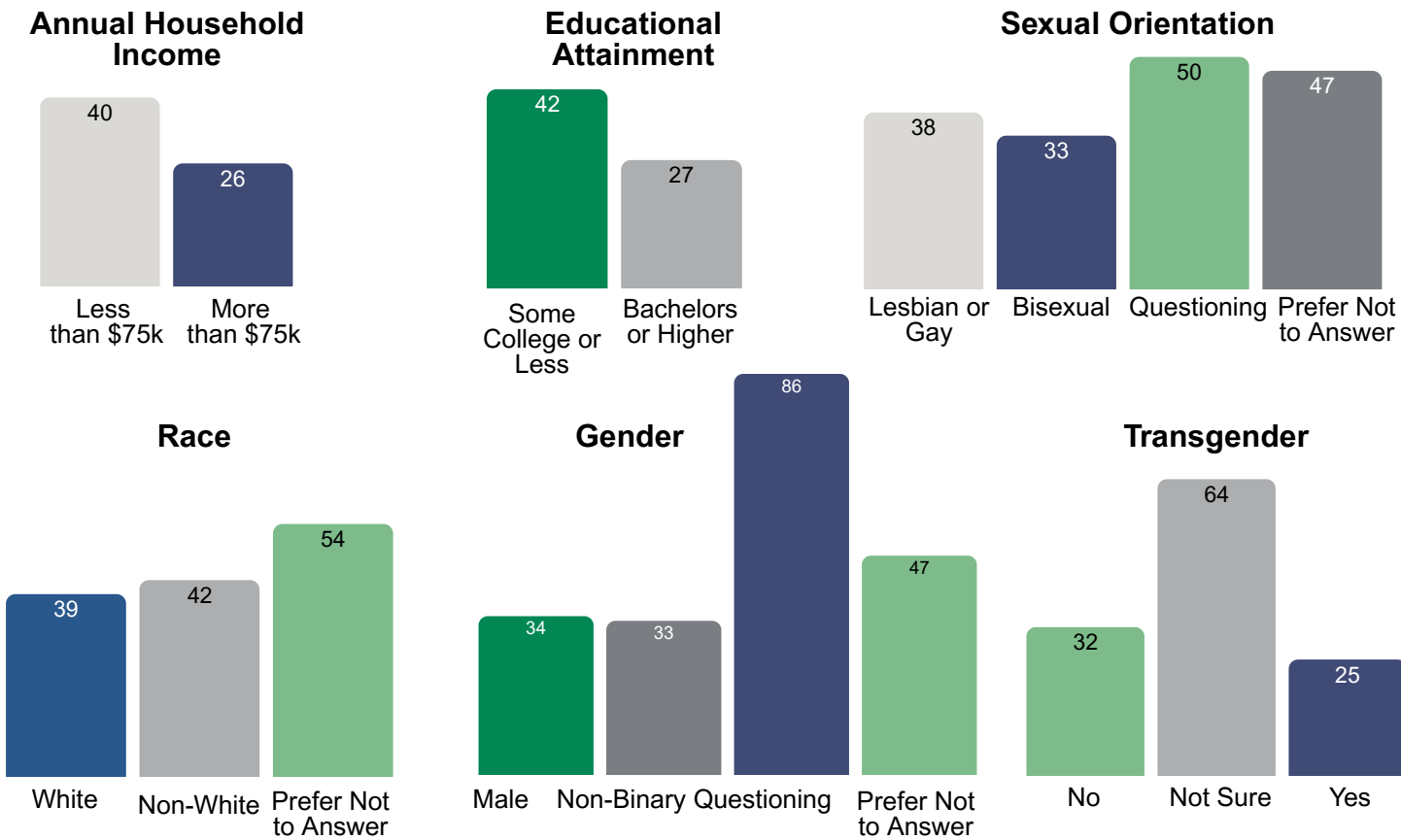
Mind Your Wellness Survey

Social & Community Context

Civic Engagement

When individuals participate in civic activities such as voting, volunteering, and community organizing, they help create social and environmental conditions that support healthier lives.

When asked if **“People like me have meaningful opportunities to influence what happens in their community,”** Community Concerns Survey participants who **disagreed** with the statement above the baseline population responded as follows:



Having a Voice & Access to Decision Making

When people feel heard and valued, they experience greater self-esteem, reduced stress, and stronger social connections, all of which contribute to overall mental and emotional health.

“I have no access to City Hall due to no accessible parking.”

-Community Concerns Survey participant



79%
of all Appleton households
self-responded
to the 2020
U.S. Census



32%
of survey participants
do not believe
people like them have meaningful
opportunities to influence what
happens in their community

Social & Community Context

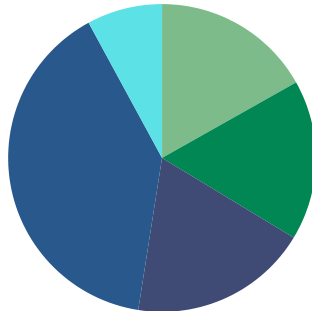


Community Safety

Top Community Concerns about Safety

When asked “**What is the greatest issue facing our community?**” on the 2023 Fall Appleton Police Department survey, responses highlighted the following:

“People drive too fast. Police need to give out more tickets.”
 -Community Concerns Survey Participant



- Traffic - 17%
- Need for Increased Public Safety - 17%
- Park/Neighborhood Issues - 19%
- Mental Health - 40%
- Community Engagement - 8%

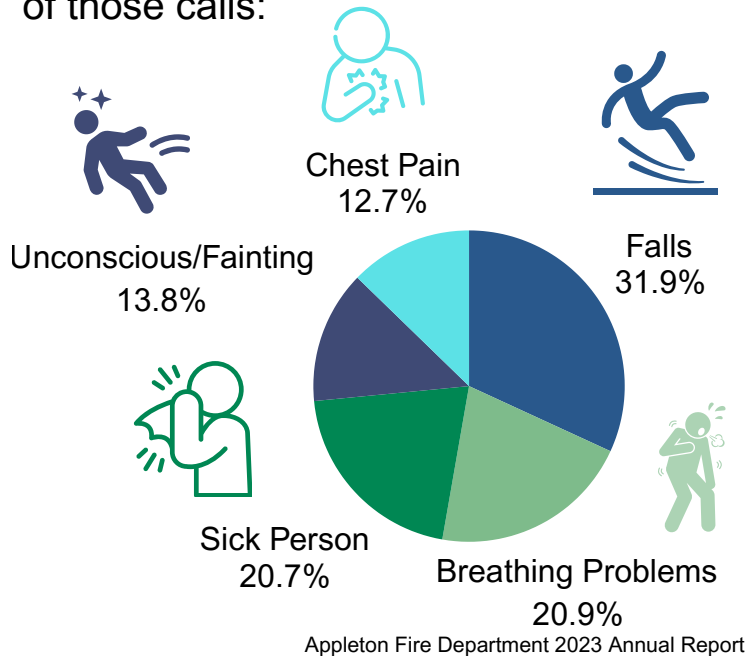
When asked “**What do you think the Appleton Police Department’s 2024 community focus should be?**” as an open-ended question, the community responded with concerns related to the following topics:

Most Common Response:	Second Most Common Response:	Third Most Common Response:
Mental Health Issues	Community Engagement	Crime & Safety

2023 Fall Appleton Police Department survey

Emergency Medical Services & Fire

In 2023, 76% of calls made to the Appleton Fire Department were medical related. Here is the breakdown of the top five of those calls:

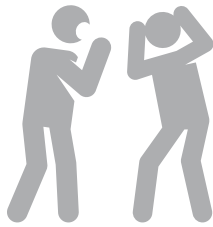


of the **4,605** high-quality fire inspections conducted in 2023, **3,124** fire code violations were identified

- #1 cause: Protection Systems
- #2 cause: Exits & Egress
- #3 cause: Fire Extinguishers

Appleton Fire Department 2023 Annual Report

Social & Community Context



Consider this:

According to the Community Concerns Survey:

1 in 4 survey participants **do not believe** our community has a fair criminal justice system

and

98% of survey participants **believe it is important or very important** that our community has a fair criminal justice system

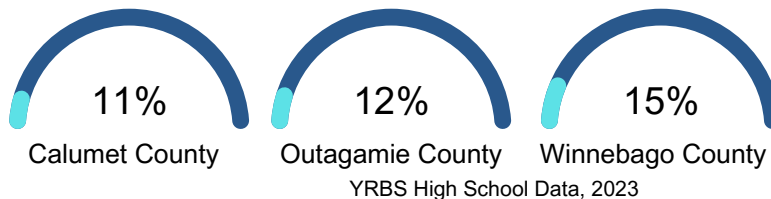
only **49%** of Community Concerns Survey participants believe **children and youth are free from abuse and neglect**

23% of Outagamie County high school students **agree that violence is a problem at school**

YRBS High School Data, Outagamie County, 2023

Neighborhood Violence

Percent of public high school students who have ever **witnessed someone get physically attacked, beaten, stabbed, or shot in their neighborhood.**



Firearm Injuries and Deaths

Firearm injuries and deaths continue to be a significant public health problem in the United States. According to the CDC, while firearm violence and injury affects people in all communities, some groups have higher rates of firearm injury than others.

Firearm Homicide Rates are highest among teens & young adults ages 15-34

Firearm Suicide Rates are highest among adults aged 75 and older

People who survive a firearm-related injury may experience long-term consequences. These include problems with memory, thinking, emotions, physical disability from injury to the brain, and paralysis from spinal cord injuries. Also included are chronic mental health problems from conditions such as post-traumatic stress disorder.

CDC Firearm Injury and Death Prevention



28% of Community Concerns survey participants reported that they **have firearms** in their household



91% of those who reported having firearms in their household said their **firearms are stored safely**



Healthcare Access & Quality

Access to Care



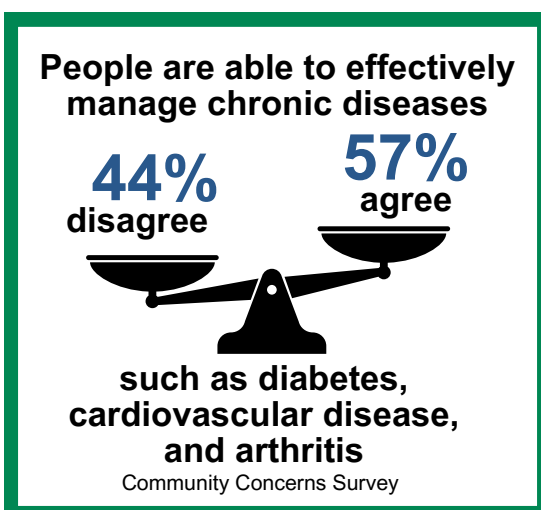
Access To Care

Healthcare access means being able to get medical care when it is needed, without too many barriers like cost, distance, or long wait times. It includes having doctors nearby, affordable services, and insurance or programs that help cover costs.

Quality of Care

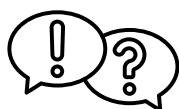
Quality of healthcare means getting the right care at the right time to stay healthy or get better. It includes safe treatments, skilled doctors, and services that meet patients' needs and comfort level without mistakes or delays.

Both access to and quality of care are crucial to public health. If individuals are unable to access care they feel comfortable going to and can afford, the ailments they suffer have a greater impact on the community as a whole.



62% of Community Concerns Survey participants think that **quality medical care and preventative screenings are available for all**

Common Barriers to Accessing Quality Healthcare



Language Barriers



Inability to Understand Insurance



Cost of Care & Medication



Lack of Reliable Transportation



Lack of Adequate Insurance



No Primary Care Provider



Distance / Location



Stigma of Asking for / Receiving Care



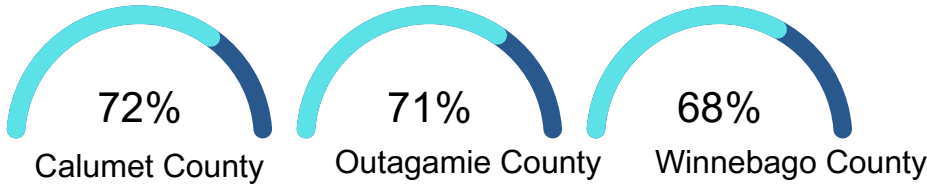
Lack of Available Providers

Healthcare Access & Quality



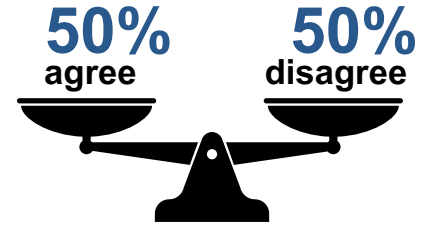
Dental Care

An estimated percent of adults aged 18 or older who report having been to the dentist or dental clinic during the past year:



CDC PLACES: Local Data for Better Health

Dental care & preventative screenings are available for all



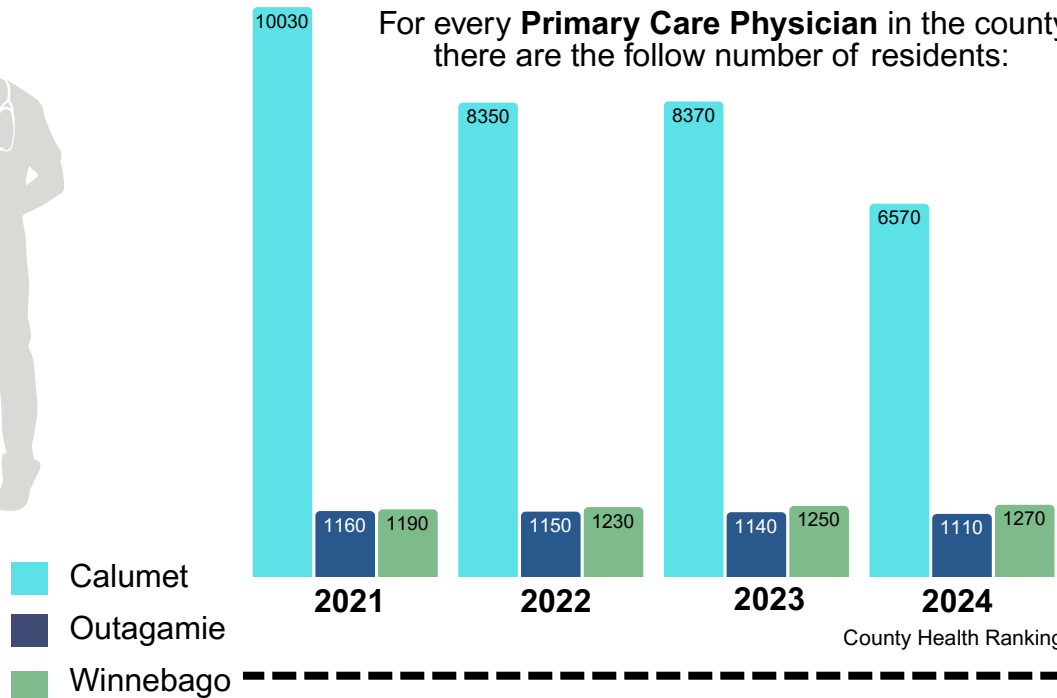
Community Concerns Survey

Primary Care

Primary care physicians include MDs and ODs under age 75 specializing in general practice, family medicine, internal medicine, and pediatrics.



For every **Primary Care Physician** in the county, there are the follow number of residents:



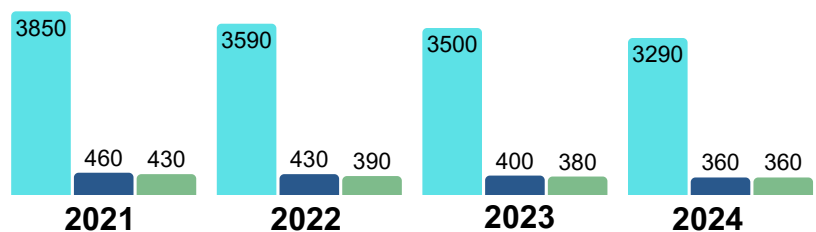
County Health Rankings

Mental Health Care



Mental Health providers are defined as psychiatrists, psychologists, licensed clinical social workers, counselors, marriage & family therapists, mental health providers that treat substance abuse, and advance practice nurses specializing in mental health care.

For every **Mental Health Provider** in the county, there are the follow number of residents:



County Health Rankings

Healthcare Access & Quality

Mental Health Care

89%

of Community Concerns Survey participants think there are **unmet mental health needs in Appleton**



only **54%**

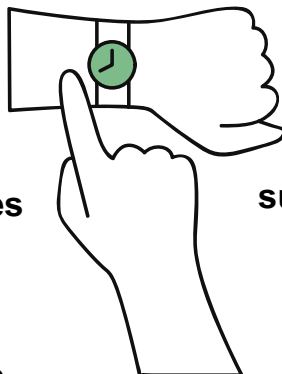
of Community Concerns Survey participants believe **mental health challenges are recognized and treated in our community**

Access to Mental Health Care

Many people can't get mental health care because it's too expensive, there aren't enough therapists, or they don't have insurance. Other barriers include long wait times, stigma, and not having services nearby, especially if one does not have reliable transportation.

only **36%**

of Community Concerns Survey participants believe **access to mental health services are available and timely**



77%

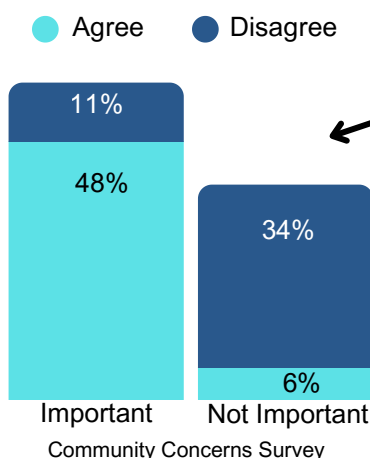
of Community Concerns Survey participants believe **suicide prevention resources are available and timely**

Quality of Mental Health Care

Mental health care quality can be poor when there aren't enough trained professionals specific to the needs of the area, treatments don't match people's needs, or care is rushed. Other issues include misdiagnosis, lack of follow-up support, and systems that focus more on quick fixes than long-term well-being.

72%

of Community Concerns Survey participants say they **know where to locate mental health resources if needed**

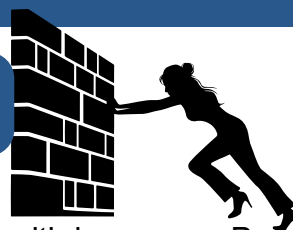


When asked if they feel like **having an opportunity to access a provider who looks like them or has a shared identity with them would increase their trust in accessing health care**, Community Concerns Survey participants had very differing views.

In total, 54% agreed with the statement, saying it is important for them to have a provider who looks like or has a shared identity as they do. However, those who agreed in the statement disagreed on if this is important or not. The majority reported a shared identity with their provider is important.

Healthcare Access & Quality

Insurance



Access to Insurance

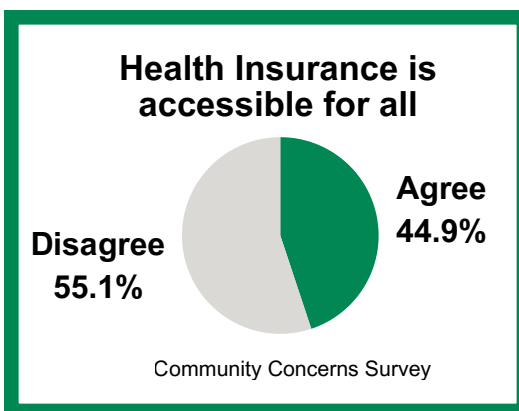
About 1 in 10 people in the United States don't have health insurance. People without insurance are less likely to have a primary care provider, and they may not be able to afford the health care services and medications they need.

Healthy People 2030, Healthcare Access & Quality

Types of Health Insurance in Wisconsin

- BadgerCare Plus (Wisconsin Medicaid): for low income adults, parents, and children
- Employer-based: employees share costs with employer
- Health Insurance Marketplace (HealthCare.gov) and the private market
- Medicaid: for people with disabilities under 65 who qualify
- Medicare: 65 or older
- Military

Winnebago County Community Health Assessment



Price as a Barrier

7.9%

of adults in Appleton report they **did not see a doctor** in the past 12 months when they needed to because they **could not afford it**

Behavioral Risk Factor Surveillance System

“I have health insurance, but I find it to be so expensive to get care that it causes me to hesitate to go in to the doctor.”
-Community Concerns Survey Participant

3.1%

of Appletonians **do not have health insurance**

American Community Survey

“Insurance cost is a joke. I make too much money for Badger Care Plus and I am ‘poverty’ level. My mental health is put on the back burner and I just want to cry.”

-Community Concerns Survey Participant

57%

of Community Concerns Survey participants say they feel access to health insurance and/or benefits

stand in the way of them changing jobs or retiring

“Securing employment used to mean securing healthcare access. That is no longer a promise employers are holding up their end of the bargain in accessing labor in our community.”

-Community Concerns Survey Participant

52%

of Community Concerns Survey participants say they feel the **cost of their health insurance limits their ability to access needed care**

Health Behaviors

Food & Nutrition

Food Insecurity

According to the USDA, “**Food Insecure households** are uncertain of having, or unable to acquire, at some time during the year, enough food to meet the needs of all their members because they had insufficient money or other resources for food. Food insecure households include those with low food security and very low food security.”

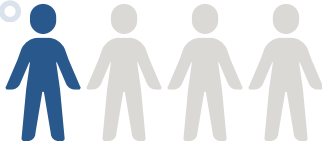
“Households with **very low food security** to the extent that normal eating patterns of some household members are disrupted at times during the year, with self-reported food intake below levels considered adequate.”

USDA, Economic Research Service: Food Security in the US Interactive Charts and Highlights



1 in 3

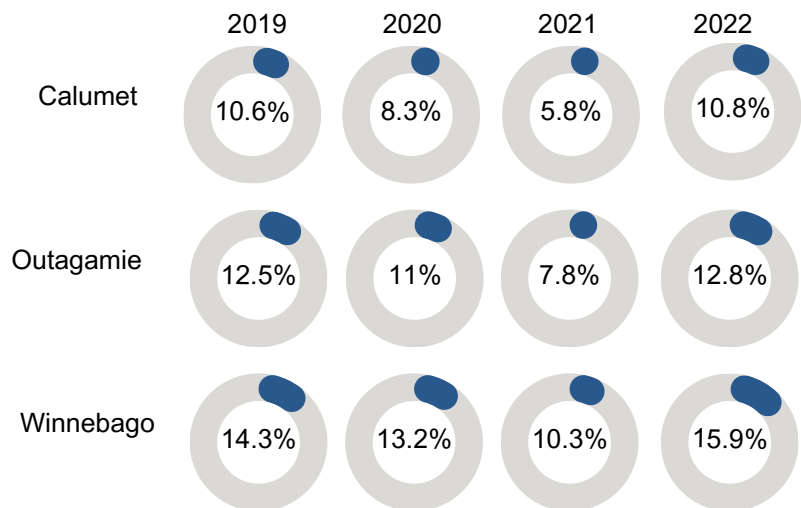
of Community Concerns Survey participants say they **do not have enough to eat**



one in four

of Community Concerns Survey participants say they worry they may **run out of food** before they have money to buy more

Estimated percent of children ages 17 and below who were food insecure during the past year



Feeding America: Map the Meal Gap



46%

of Community Concerns Survey participants say **healthy foods are NOT available and affordable**



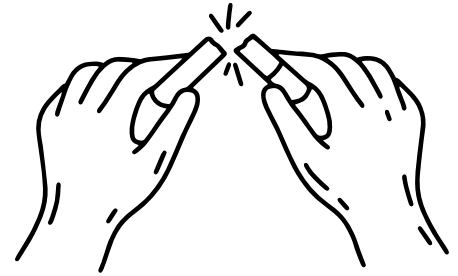
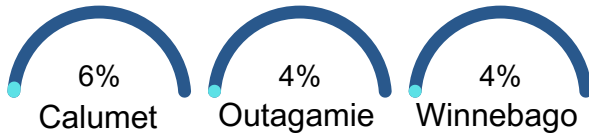
Health Behaviors

Substance Use

Tobacco & Vaping Use



Percent of public middle & high school students who have used cigarettes, chew, cigars or cigarillos in the past 30 days



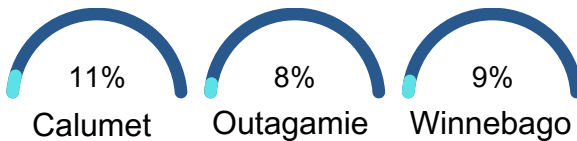
of the high school students who used tobacco or vaping products, almost

half

have tried to quit in the past year



Percent of public middle & high school students who used vaping products in the past 30 days



Wisconsin Department of Public Instruction, YRBS Reports

Did you know?

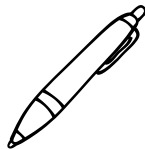
Vapes are easily concealed as



Hooded Sweatshirt



Backpack



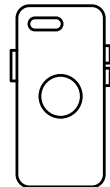
Pen



USB Drive



Smart Watch

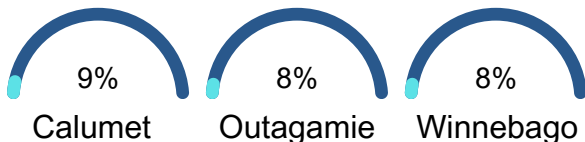


Phone Case

Six Vaping Products Disguised as Everyday Items, Healthline.com

Misuse of Pain Medication

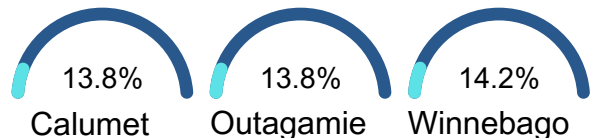
Percent of public middle & high school students who have ever misused over-the-counter and/or prescription pain medicine



Wisconsin Department of Public Instruction, YRBS Reports



Percent of adults (18+) who are current smokers



CDC, Places

Health Behaviors

Alcohol Use

Binge Drinking

Men = five or more drinks
Women = four or more drinks



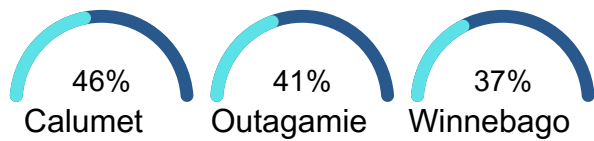
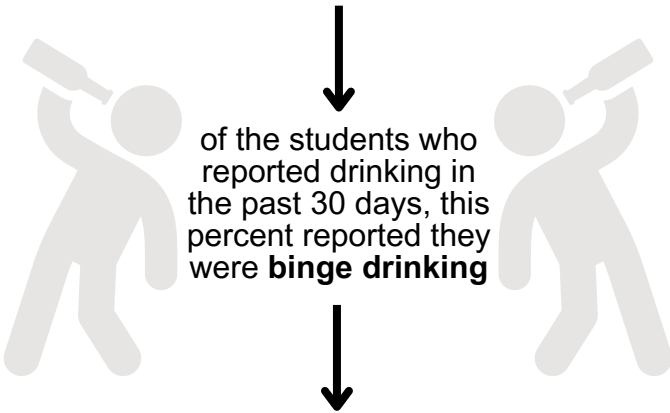
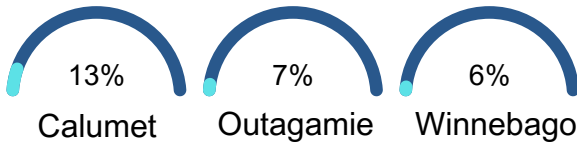
Heavy Drinking

Men = more than 2 drinks/day on average
Women = more than 1 drink/day on average



Alcohol Use of Middle & High School Students

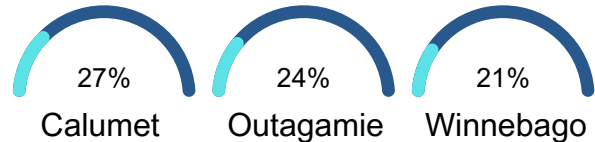
Students who report they drank in the last 30 days



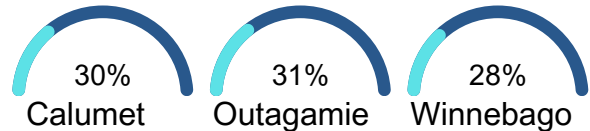
Wisconsin Department of Public Instruction, YRBS Reports

Alcohol Use of Adults

Percent of adults aged ≥18 years who report **binge drinking** at least one time in the past 30 days



Percent of adults who report **heavy drinking** during the past 30 days



Wisconsin Department of Health Services Alcohol Use Dashboard

“Wisconsinites in every age group engaged in more binge drinking than the U.S. median for that age group. **Wisconsinites ages 25-44 had the highest proportion of binge drinkers.**”

Alcohol: Adult Use Dashboard, WI DHS (2023)

Did you know?

there are **186** total alcohol licenses in Appleton



there are **397.26** people per alcohol license in Appleton

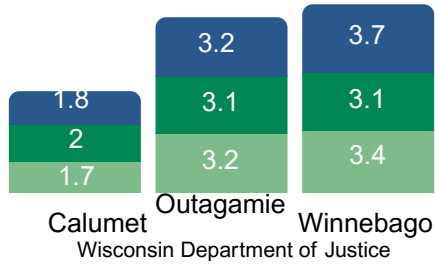
Wisconsin Environmental Public Health Tracking Program

Health Behaviors

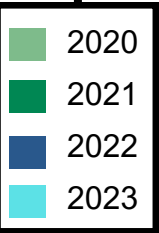
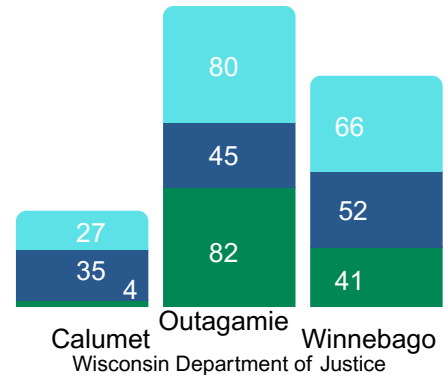


Alcohol Statistics

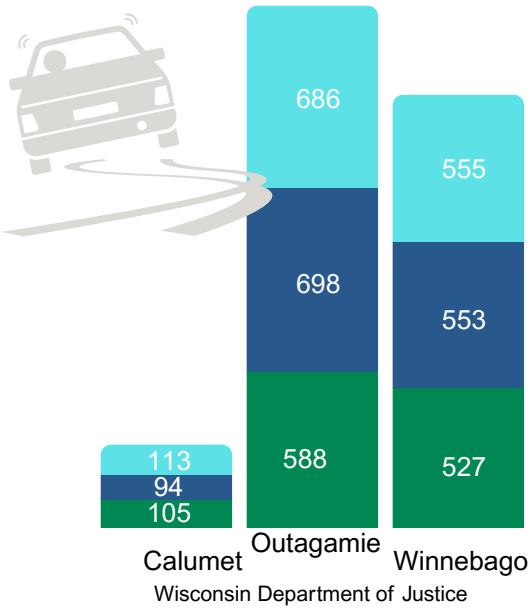
DUI Arrest Rates per 1,000 residents in each county



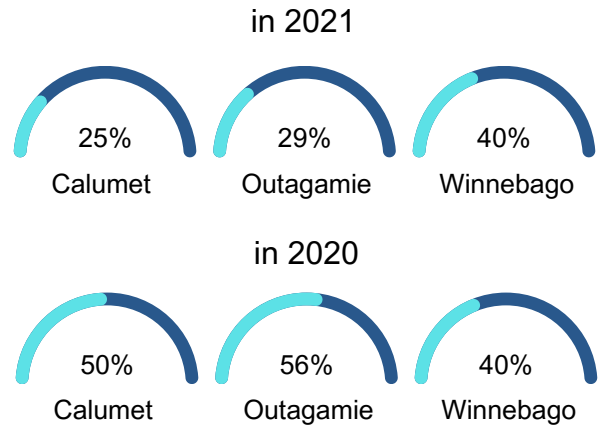
Number of Juvenile Liquor Law Arrests in each county



Total Number of DUI Arrests in each county

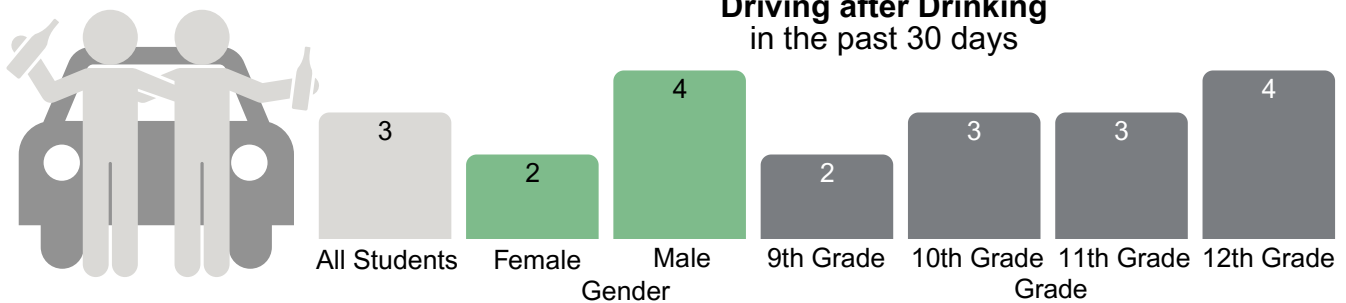


Percentage of Driving Deaths with alcohol involvement



Wisconsin Department of Transportation, Fatality Analysis Reporting System

Percentage of student drivers who reported Driving after Drinking in the past 30 days



Outagamie County 2023 High School YRBS Results

Health Behaviors

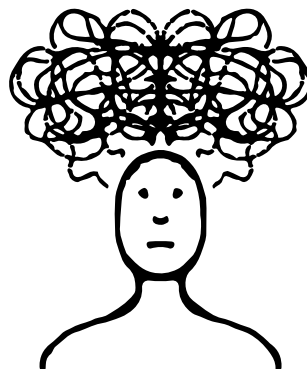
Mental Health



25.5%

of adults in Appleton have been told by a doctor, nurse, or other health professional they had a depressive disorder, including **depression, major depression, dysthymia, or minor depression**

CDC Places



16.7% of adults in Appleton who report that their **mental health** (including stress, depression, and problems with emotions) was **not good** for 14 or more days during the past 30 days

CDC PLACES

Depression

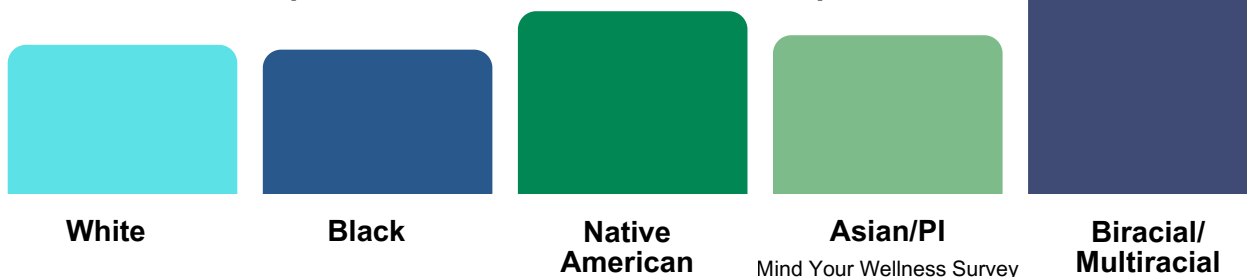
Depression is a common and serious mood disorder. It causes severe symptoms that affect how you feel, think, and handle daily activities, such as sleeping, eating, or working. In 2022, an estimated 54 million U.S. adults (21%) reported they had been told by a doctor they had a depressive disorder, including depression, major depression, dysthymia, or minor depression in their lifetime. CDC, Health Outcomes

Depression, even the most severe cases, can be treated.
The earlier treatment begins, the more effective it is.

CDC, Health Outcomes



Comparison of Individuals who Feel Depressed



Income Matters



Mind Your Wellness survey respondents reported that if they make **\$150,000 + a year** they are much more likely to **know how to access mental health care** than those who make less than \$150,000 a year

Social & Community Context

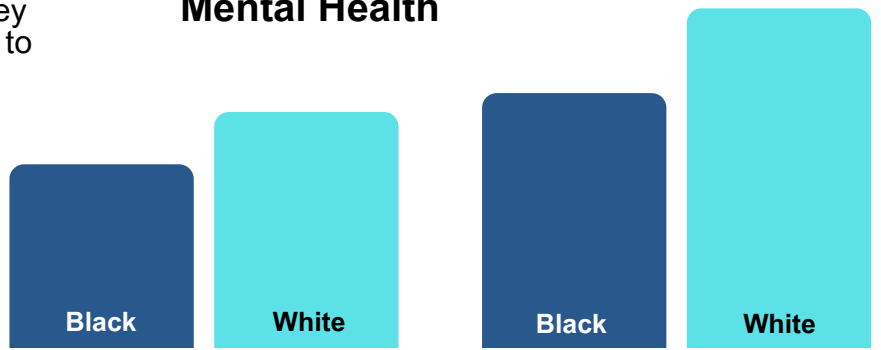
The Mind Your Wellness Survey reported that, when compared to white individuals,

Black individuals are:

- **Less likely** to report symptoms of depression
- **Less likely** to report symptoms of anxiety
- **More likely** to get fewer hours of sleep



Mental Health



No Anxiety

Black individuals are almost **50% less likely to report symptoms of anxiety** than white individuals

Mind Your Wellness Survey

Not in Treatment

Black individuals are almost **60% less likely to be in treatment** than white individuals

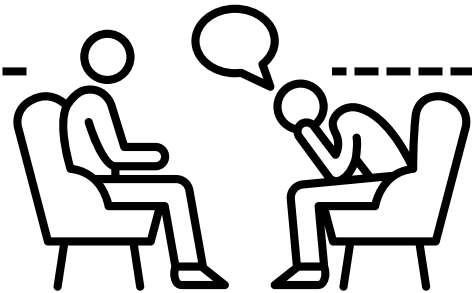
Mind Your Wellness Survey

The Mind Your Wellness Survey reported that, when compared to non-LGBTQ+ individuals,

LGBTQ+ individuals are:

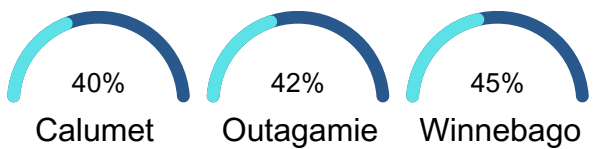
- **More likely** to get fewer hours of sleep
- **More likely** to experience symptoms of depression over the past 12 months
- Almost **twice as likely** to experience symptoms of anxiety over the past 12 months
- **1.8 times more likely** to engage in self-inflicted injury
- Almost **twice as likely** to report considering suicide in the past 12 months
- **Less likely** to feel rested upon waking
- **More likely** to be living with chronic pain
- **Twice as likely** to always feel isolated

Mind Your Wellness Survey

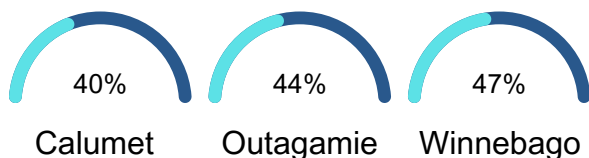


Percentage of public school students who have experienced **Significant Problems with Anxiety** in the past 12 months

in 2023



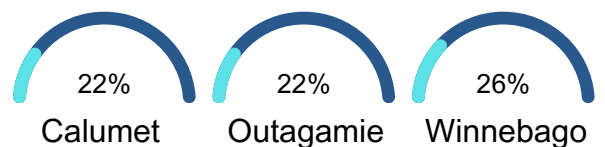
in 2021



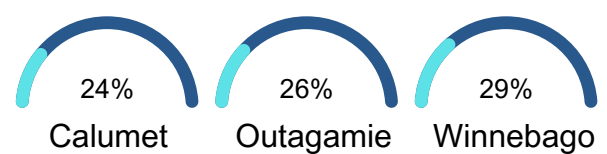
Wisconsin Department of Public Instruction, YRBS Reports

Percent of public school students who **felt so sad or hopeless** almost every day for two or more weeks in a row that they stopped usual activities in the past 12 months

in 2023



in 2021



Wisconsin Department of Public Instruction, YRBS Reports

Health Behaviors



Suicidal Behavior

Mind Your Wellness survey respondents who report they have considered suicide in the past 12 months are 33 times more likely to report symptoms of depression and 39 times more likely to have symptoms of anxiety.



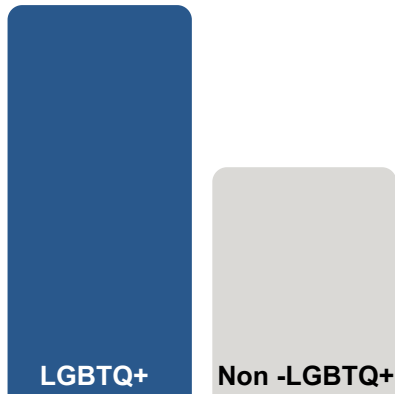
1 in 10

Mind Your Wellness survey respondents report considering attempting suicide during the past 12 months



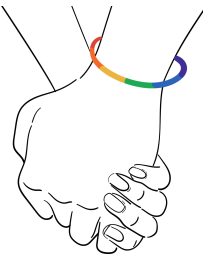
1 in 20

Mind Your Wellness survey respondents report planning a suicide attempt during the past 12 months



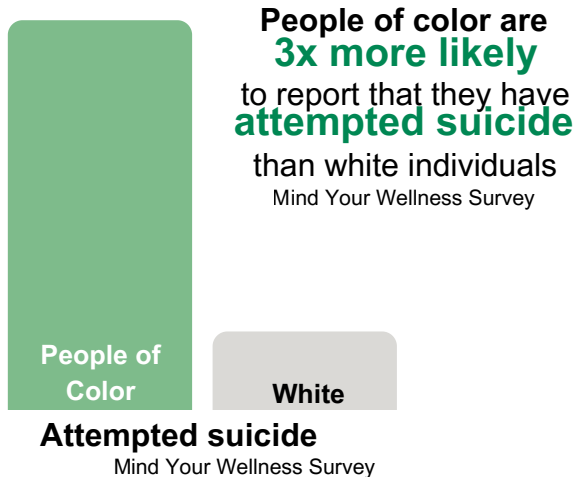
Considered suicide in the past 12 months

LGBTQ+ folks are **11 times more likely** to report that they have **attempted suicide** at least once in the past 12 months when compared with non-LGBTQ+ survey participants



Attempted suicide at least once in the past 12 months

Mind Your Wellness Survey



People of color are **3x more likely** to report that they have **attempted suicide** than white individuals
Mind Your Wellness Survey

Attempted suicide
Mind Your Wellness Survey



In Crisis?

**988
LIFELINE**

When you call, text, or chat the 988 Lifeline, your conversation is free & confidential. Talking with someone can help save your life.

Health Behaviors

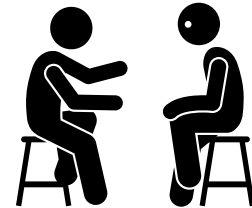
Coping Skills

Help-Seeking Behavior

85%
of Mind Your Wellness
survey respondents
feel comfortable
discussing mental health
issues with others

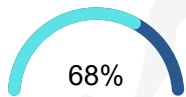


84%
of Community Concerns
Survey participants say they
would use an Employee
Assistance Program (EAP)
to get help if needed

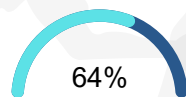


89%
of Community Concerns
Survey participants say they
would use a support
program to get help if
needed

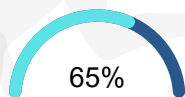
Percent of public
middle & high school
students who
exercised 4-7 days in
the past week



Calumet



Outagamie



Winnebago

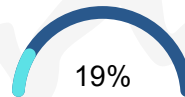
Wisconsin Department of Public Instruction, YRBS Reports

Physical Activity

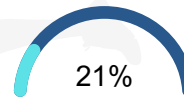
Percent of adults
(18+) reporting no
leisure time physical
activity



Calumet



Outagamie



Winnebago

CDC PLACES

Screen Time



Those who get
4+ hours
of non-work-related
screen time
daily are
twice as likely
to report symptoms of
anxiety
than those getting fewer than 4
hours of screen time
Mind Your Wellness Survey

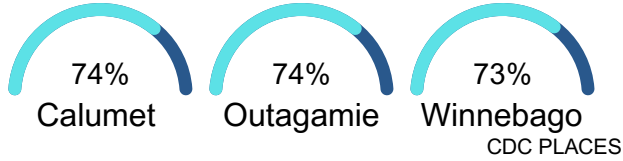


Health Behaviors

Chronic Disease

Prevention

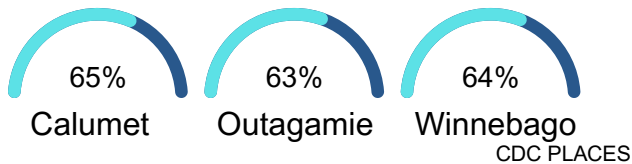
Estimated percent of **females aged 50–74 years** who report having **had a mammogram** within the previous 2 years



The US Preventive Services Task Force recommends that women who are 40 to 74 years old and are at average risk for breast cancer get a mammogram every 2 years.

↑
Did you know?
↓

Estimated percent of population **age 50 - 75** who have received **colon cancer screening** according to current guidelines

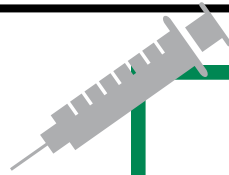
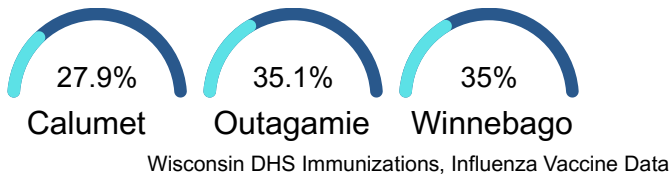


The US Preventive Services Task Force recommends that people should begin screening for colorectal cancer soon after turning 45 and continue screening every 5-10 years.

CDC PLACES

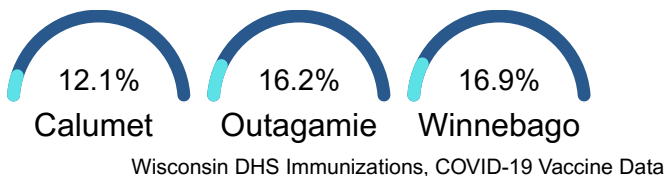
Immunizations

Percent of population who had **at least one dose of the influenza vaccine** during the 2023 - 2024 influenza season.

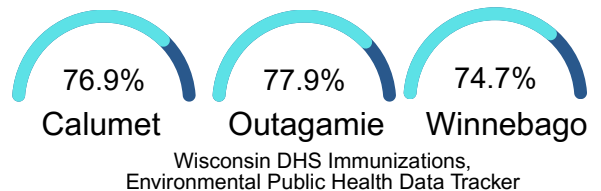


92%
of Community Concerns Survey participants believe it is **important or very important** that **children, youth, and adults are up to date on their immunizations**

Percent of population who received **at least one dose of the updated COVID-19 vaccine**



Percent of **children aged 24 months** who have completed the **4:3:1:3:3:1:4** series of **seven vaccines**



This series includes: 4 doses of DTaP, 3 doses of polio, 1 dose of MMR, 3 doses of Haemophilus influenzae type b, 3 doses of hepatitis B, 1 dose of varicella, and 4 doses of pneumococcal conjugate vaccine.

Health Behaviors

Human Milk



77%
of infants were breastfed before being discharged from the hospital, compared to

18%
of infants who were *not* breastfed before being discharged from the hospital

Wisconsin DHS WISH Query, Birth Counts Module

Sexual Activity

Percent of **public high school students** who have had **sexual intercourse** in the past three months



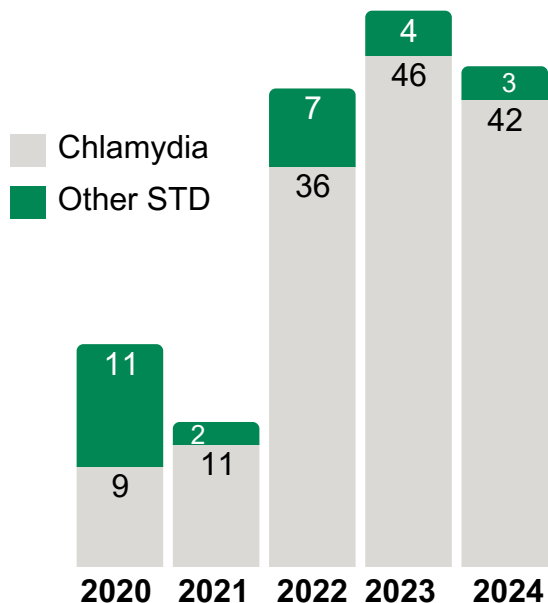
of those students, this **percent** used a **condom** during their last sexual intercourse experience



Wisconsin Department of Public Instruction, YRBS Reports

38%
of Community Concerns Survey participants do not think people engage in safe-sex practices

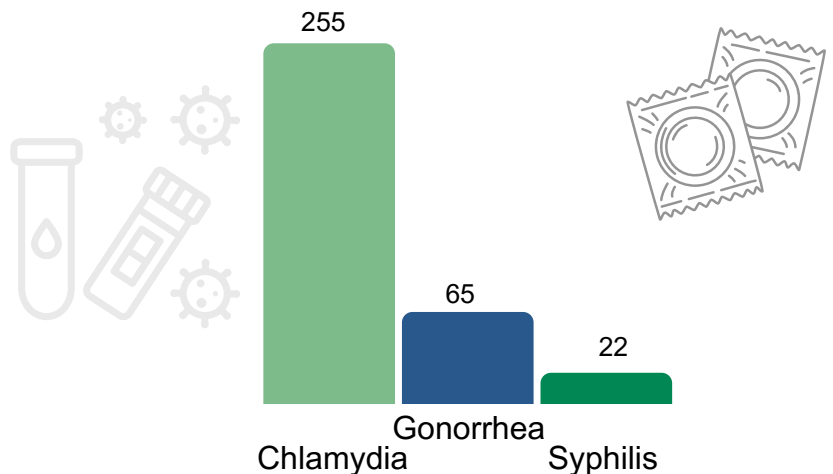
Sexually Transmitted Diseases in Youth (18 and under)



Wisconsin Department of Public Instruction, YRBS Reports

Sexually Transmitted Diseases in Adults

In 2023, there were the following amount of confirmed and probable cases of STIs in Appleton:

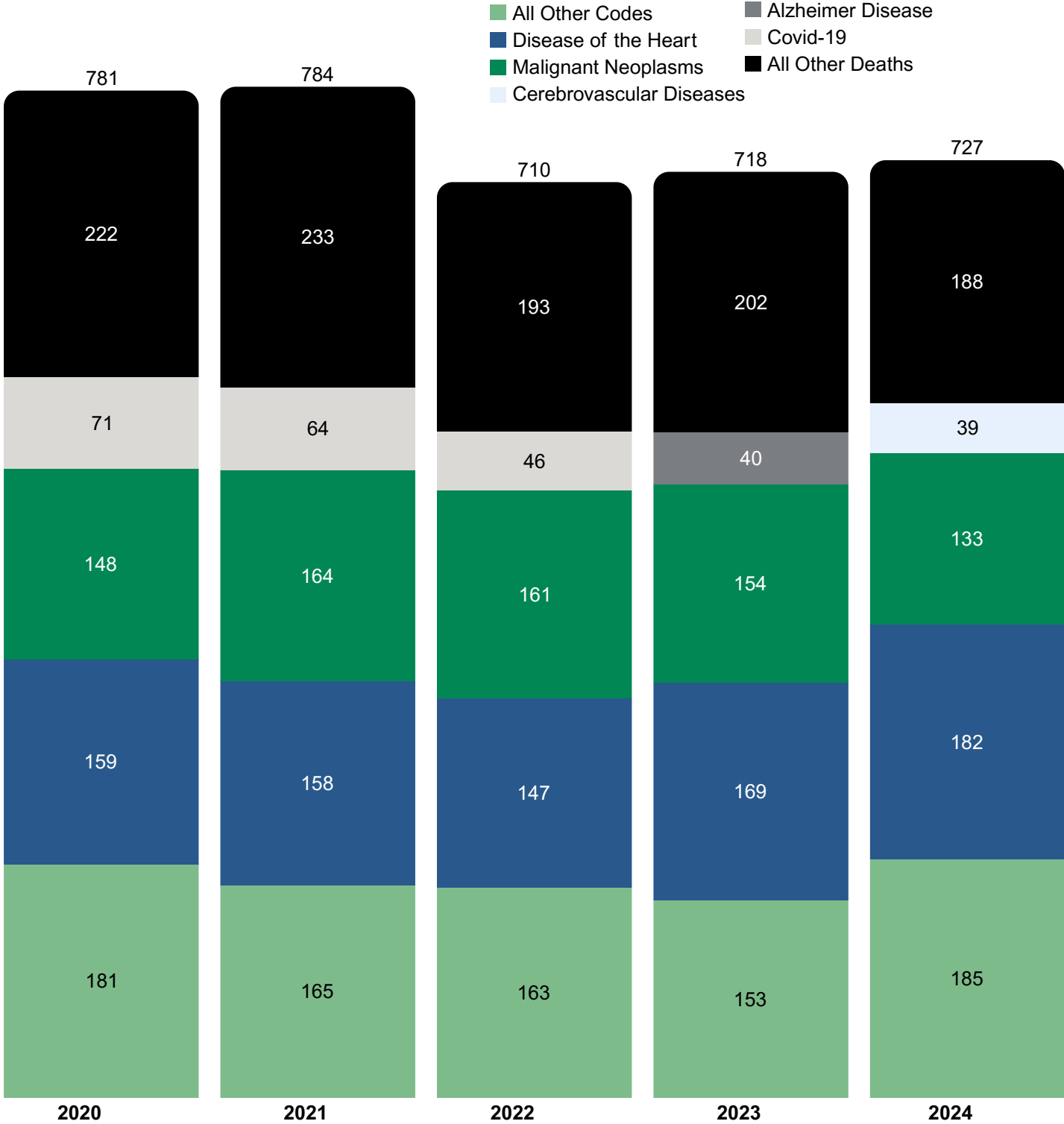


WEDS Data, 2023

Health Outcomes

Cause of Death

The following represent the **top 5 causes of death** in Appleton from 2020-2024:



City of Appleton Health Department's Annual Reports 2020 - 2024

Next Steps

Tri-County CHIC

Where do we go from here?

From now on, we will work with the Tri-County Community Health Improvement Coalition (CHIC) to complete a more intensive Community Health Assessment and Community Health Improvement Plan.

All five local public health agencies, four area health systems, and numerous diverse community organizations have come together with a shared purpose: to improve health and well-being for every individual in our communities. This isn't just about identifying a priority—it's about committing to action. Our collective focus on health and well-being means the community can expect real, meaningful change. This collaborative effort is more than an assessment—it's a promise.

A promise that we will invest our time, energy, and resources to create a community that is responsive, inclusive, and lasting. We know this work takes time. It requires listening, relationship-building, and trust. It means working through challenges and designing solutions, all of which we have begun doing together. But the reward is worth it: a future where health and well-being is not an afterthought but a foundation of the work in each of our organizations.

- Advocate Aurora Health
- Ascension
- Calumet County Public Health
- Casa Hispana
- Children's Wisconsin
- City of Appleton Health Department
- City of Menasha Health Department
- Diverse and Resilient
- Fox Valley Data Exchange
- Hmong American Partnership Fox Valley
- NEW Hmong Professionals
- NEW Mental Health Connection
- Outagamie County Public Health Division
- Partnership Community Health Center
- People of Progression
- Samaritan Fox Valley
- ThedaCare
- United Way Fox Cities
- Winnebago County Health Department
- YMCA of the Fox Cities



DEPARTMENT OF
**PUBLIC
HEALTH**

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Common Terms in Public Health

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<http://crchd.cancer.gov/disparities/defined.html>
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- <https://pubmed.ncbi.nlm.nih.gov/1644507/>
- https://phaboard.org/wp-content/uploads/PHABSM_WEB_LR1-1.pdf
- http://www.who.int/social_determinants/en/
- www.nlm.nih.gov
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Frameworks & Models

- <https://www.cdc.gov/public-health-gateway/php/index.html>

Demographic Snapshot

- <https://www.census.gov/library/visualizations/interactive/2020-census-self-response-rates-map.html>

Economic Conditions

- [https://data.census.gov/table?q=B19013&g=010XX00US_040XX00US55,55\\$0500000](https://data.census.gov/table?q=B19013&g=010XX00US_040XX00US55,55$0500000)
- <https://www.countyhealthrankings.org/explore-health-rankings/county-health-rankings-model/health-factors/social-economic-factors/census-participation?year=2023>
- [https://data.census.gov/table?q=B20017&g=01XX00US_04XX00US55,55\\$0500000](https://data.census.gov/table?q=B20017&g=01XX00US_04XX00US55,55$0500000)
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Economic Conditions Cont.

- <https://www.newmentalhealthconnection.org/wp-content/uploads/2022/09/MYWS-deep-dive-presentation-09.29.22.pdf>
- <https://worldpopulationreview.com/state-rankings/cost-of-living-index-by-state>
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- <https://scorecard.prosperitynow.org/data-by-issue#finance/outcome/households-with-zero-net-worth>
- <https://www.healthinsurance.org/glossary/federal-poverty-level/>
- https://uwcm.org/wp-content/uploads/2024/03/BENEFITS-CLIFF-STUDY-FINAL-7_24_20.pdf
- <https://www.unitedforalice.org/county-reports/wisconsin#7/44.832/-89.835>

Neighborhood & Built Environment

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- <https://www.wiboscoc.org/point-in-time.html>
- <https://dhsgis.wi.gov/DHS/EPHTracker/#/all/Oral%20Health/oralHealthIndex/NOTRACT/Population%20on%20Fluoridated%20Public%20Water%20System/OHPFPWSPercPop>
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Education Access & Quality

- <https://nces.ed.gov/surveys/piaac/skillsmap/>
- [https://data.census.gov/table/ACSST1Y2021.S1501q=educational+attainment&g=040XX00US55,55\\$0500000&moe=false](https://data.census.gov/table/ACSST1Y2021.S1501q=educational+attainment&g=040XX00US55,55$0500000&moe=false)
- [https://data.census.gov/table/ACSDT1Y2021.B14005q=B14005&g=010XX00US_040XX00US55,55\\$0500000&moe=false](https://data.census.gov/table/ACSDT1Y2021.B14005q=B14005&g=010XX00US_040XX00US55,55$0500000&moe=false)

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Social & Community Context

- [https://www.census.gov/library/visualizations/interactive/2020-census-self-response-rates-map.html%20\(2\)%20County%20Health%20Rankings:%20https://www.countyhealthrankings.org/explore-health-rankings/county-health-rankings-model/health-factors/social-economic-factors/census-participation?year=2023](https://www.census.gov/library/visualizations/interactive/2020-census-self-response-rates-map.html%20(2)%20County%20Health%20Rankings:%20https://www.countyhealthrankings.org/explore-health-rankings/county-health-rankings-model/health-factors/social-economic-factors/census-participation?year=2023)
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- <https://dpi.wi.gov/sspw/yrbs>
- <https://nccd.cdc.gov/Youthonline/App/Default.aspx>

Healthcare Access & Quality

- <https://www.countyhealthrankings.org/health-data/community-conditions/health-infrastructure/clinical-care/mental-health-providers?year=2025>
- <https://odphp.health.gov/healthypeople/objectives-and-data/browse-objectives/health-care-access-and-quality>
- <https://www.cdc.gov/places/index.html>

Health Behaviors

- <https://www.newmentalhealthconnection.org/wp-content/uploads/2022/09/MYWS-deep-dive-presentation-09.29.22.pdf>
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The following is an example of the advertisements for the Community Concerns Survey.



I hope you take the survey:
“So the city can better understand how to better meet the needs of its community.”

One area I see opportunity is:
“The concerns I mentioned in my responses aren’t areas the city have the ability to address, e.g. the cost of health care and groceries.”

Dennetra Williams & her daughter Peyton

Appendix A



City of Appleton's Community Concerns Survey

1. Which of the following apply? (Select all that apply)

- I live in Appleton.
- I work in Appleton.
- I choose to spend some of my free time in Appleton.
- I rarely or never spend time in Appleton.

Rate Your Community on the Following

For the following questions your answer should be based on what you think the experience is for everyone in Appleton. For questions that start with "I..." please answer based on your own experience.

2. Social and Community Conditions

	How much do you agree? (Circle one)	How important is this? (Circle one)
People have opportunities to receive high-quality education or skills training.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
Our community is walkable/bikeable/wheelable.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
Transportation is available to people of all ages and abilities.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
People have enough to eat.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important

Appendix A

Breastfeeding is promoted and supported by the community.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
	How much do you agree? (Circle one)	How important is this? (Circle one)
Quality childcare is available and affordable.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
People are able to find jobs that support themselves and their families.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
People are able to keep jobs that support themselves and their families.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
Safe and affordable housing is available.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
My neighborhood is racially diverse.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
Adults refrain from abusing drugs and tobacco.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
Adults refrain from abusing alcohol.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important

Appendix A

Youth do not use drugs or tobacco.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
Youth do not abuse alcohol.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
	How much do you agree? (Circle one)	How important is this? (Circle one)
Schools in Appleton provide quality education.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
Employers do not take advantage of people who are vulnerable.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
People like me have meaningful opportunities to influence what happens in their community.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important

Appendix A

3. Physical, Mental, & Systemic Safety

	How much do you agree? (Circle one)	How important is this? (Circle one)
Healthy foods are available and affordable.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
Children and youth are free from abuse and neglect.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
People are free from the threat of physical and sexual violence.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
People are treated fairly and without discrimination.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
Our community has a fair criminal justice system.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
Adults do not engage in aggressive or threatening behavior.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
Children do not engage in aggressive or threatening behavior.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
People engage in safe-sex practices.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important

Appendix A

	How much do you agree? (Circle one)	How important is this? (Circle one)
I feel that my community supports me in obtaining my health goals.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important

Appendix A

4. Mental Health & Wellbeing

	How much do you agree? (Circle one)	How important is this? (Circle one)
People are free from chronic stress.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
Mental health challenges are recognized and treated in our community.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
Access to mental health services are available and timely.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
Suicide prevention resources are available and timely.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
	How much do you agree? (Circle one)	How important is this? (Circle one)
People in Appleton enjoy a good quality of life.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
There are unmet mental health needs in Appleton.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
I would use an Employee Assistance Program (EAP) to get help if needed.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
I would use a support program to get help if needed.	Strongly Agree Agree	Very Important Important

Appendix A

	Disagree Strongly Disagree	Not Important Not at All Important
	How much do you agree? (Circle one)	How important is this? (Circle one)
I know where to locate mental health resources if I need them.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
I am comfortable getting mental health help in my community.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important

Appendix A

5. Person & Community Centered Health Care

	How much do you agree? (Circle one)	How important is this? (Circle one)
Children, youth, and adults are up to date on their immunizations.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
Quality medical care and preventive screenings are available for all.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
	How much do you agree? (Circle one)	How important is this? (Circle one)
Dental care and preventive screenings are available for all.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
People are able to effectively manage chronic diseases, such as, diabetes, cardiovascular disease, and arthritis.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
Health insurance is accessible for all.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
I feel the cost of my health insurance limits my ability to access needed care.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
I am able to understand health insurance coverage and benefits.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
I feel access to health insurance and/or benefits stand in the way of me changing jobs or retiring.	Strongly Agree Agree	Very Important Important

Appendix A

	Disagree Strongly Disagree	Not Important Not at All Important
	How much do you agree? (Circle one)	How important is this? (Circle one)
I feel having an opportunity to access a provider who looks like me or has a shared identity with me would increase my trust in accessing health care.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important

Appendix A

6. Social Connectedness & Belonging

	How much do you agree? (Circle one)	How important is this? (Circle one)
People in the community have adequate emotional and social support.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
I feel connected to others in my community.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
I feel connected to others in my community.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
I feel I belong in my community.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
If I needed help, I have friends or family who could help me any time of day or night.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
I lack companionship.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
I feel left out.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
I feel isolated from others.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important

Appendix A

Basic Needs

For the following questions your answer should be based on your own experience.

7. Economic Stability

	How much do you agree? (Circle one)	How important is this? (Circle one)
If I was suddenly without income for one month, I would be able to cover all my household expenses.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
I can pay all my bills every month.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
At the end of every month, I am able to save money.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important
Living in Appleton is affordable.	Strongly Agree Agree Disagree Strongly Disagree	Very Important Important Not Important Not at All Important

8. In the last 12 months, how often have you been worried that you would run out of food before you had money to buy more? (choose one)

- Often (more than 10 times)
- Sometimes (3 - 10 times)
- Rarely (1 – 2 times)
- Never

9. Does your household have enough money to pay for basic needs like food, clothing, housing, etc.?

- Yes
- No
- Sometimes

Appendix A

10. What is your living situation today? (choose one)

- I have housing and I am NOT worried about losing it.
- I have housing, but I AM worried about losing it.
- I have housing, but it does not meet my needs.
- I do NOT have housing and I am temporarily staying with friends/family.
- I do NOT have housing and I am temporarily staying in a shelter.
- I do NOT have housing and I am temporarily staying in a vehicle.
- I do NOT have housing and I am living on the street, in a park, etc.

11. Do any of the following impact your ability to keep your job or move up in your job? (Select all that apply.)

- My ability to get job skills training
- My education level
- Availability of childcare
- Availability of respite care
- Availability of reliable transportation
- Concern for loss of benefits and/or insurance
- Job accommodations for disability
- Language barrier
- Other (please specify) _____
- None of the above

12. Where do you get most of your food? (choose one)

- "Big Box" grocery store (Festival, Pick'n'Save, Woodman's, Aldi, Target, Walmart)
- Kwik Trip
- Convenience store or gas station (NOT Kwik Trip)
- Dollar Store (Dollar General, Family Dollar, Dollar Tree)
- Local ethnic markets
- Seasonal farmer's markets
- Food pantry
- Personal garden/farm
- Community gardens
- Restaurants
- Fast Food
- Other (please specify) _____

Appendix A

Emergency Preparedness

For the following questions your answer should be based on your own experience.

13. Does your household have any of the following emergency plans?

	Yes	No	Don't Know
Emergency communication plan (Such as a list of phone numbers and designated out-of-town contacts)			
Designated meeting place immediately outside your home or close by in your neighborhood.			
Designated meeting place outside of your neighborhood in case you cannot return home.			
Copies of important documents in a safe location (e.g. water/fire proof container)			
Multiple routes away from your home in case evacuation is necessary			

14. If public authorities announced a mandatory evacuation from your community due to a large-scale disaster or emergency, would your household evacuate?

- Yes
- No
- Don't Know

15. If your household had to evacuate due to a disaster or emergency, where would your household go outside of Appleton?

- Friends/Family/Second home outside of the area
- Hotel or motel
- American Red Cross shelter, church, or community shelter
- Vehicle or RV
- Would not evacuate
- Other (please specify) _____

Appendix A

16. In an emergency, if your household was asked to evacuate, what your household do with your pet(s)?

- Take pet(s) with you
- Find a safe place for pet(s)
- Leave pet(s) behind with food and water
- Would not evacuate because of pet(s)
- Would not evacuate
- No pet(s)
- Don't know
- Other (please specify) _____

17. What would be the main reason that may prevent your household from evacuating if asked to do so?

- Lack of transportation
- Concern about personal safety
- Health problems
- Lack of trust in public officials
- Concern about leaving pet(s)
- Concern about traffic jams
- Nowhere to go
- Inconvenient/Expensive
- No reason, would evacuate
- Don't know
- Other (please specify) _____

Appendix A

Demographics

For the following questions your answer should be based on your own experience.

18. Which racial/ethnic group(s) do you identify with? (select all that apply)

- Afghan
- African (e.g., Congolese, North African, South African)
- Alaskan Native
- Arab
- Asian—Hmong
- Asian—non-Hmong
- Black
- Hispanic or Latinx (e.g., Columbian, Mexican, Puerto Rican)
- Indian (from India)
- Middle Eastern
- Multiracial
- Native or Indigenous (e.g., Chippewa or Ojibwe, Ho-Chunk, Menominee, Oneida, Potawatomi)
- Native Hawaiian or Pacific Islander
- White
- Prefer not to answer
- Other (please specify) _____

19. Including yourself, how many people live in your household?

- 1 - Just me
- 2 - me and one other person
- 3 - me and two other people
- 4 - me and three other people
- 5 - me and four other people
- 6 - me and five other people
- 7 - me and six other people
- 8 - me and seven other people
- 9 - me and eight other people
- 10 - me and nine other people
- More than 10

Appendix A

20. How many children under the age of 18 live in your household?

- None
- 1
- 2
- 3
- 4
- 5
- 6 or more

21. Do other individuals besides your partner and/or children live in your household?

- Grandparent
- Parent
- Adult relative
- Youth relative
- Friend
- N/A
- Other (please specify) _____

22. Choose the option that best describes your current employment status. (choose one)

- Full-time employed
- Part-time employed
- Seasonal employment
- Stay at home parent
- Full-time caregiver for an adult family member
- Retired
- Unable to work
- Unemployed
- Other (please specify) _____

23. What is the highest level of education you completed? (choose one)

- Full-time employed
- Some high school
- High School / GED
- Some college
- Trade / technical / vocational training
- Associate Degree
- Bachelor's Degree
- Graduate or Professional Degree

Appendix A

24. Which language(s) do you speak at home? (select all that apply)

- Dari/Farsi
- English
- Hmong
- Kinyarwanda
- Spanish
- Swahili
- Other (please specify) _____

25. What is your annual household income? (choose one)

- Under \$15,000
- Between \$15,000 and \$29,999
- Between \$30,000 and \$49,999
- Between \$50,000 and \$74,999
- Between \$75,000 and \$99,999
- Between \$100,000 and \$150,000
- Over \$150,000

26. Select the option which best describes your gender.

- Female
- Male
- Non-Binary
- Questioning
- Prefer not to say
- Other (please specify) _____

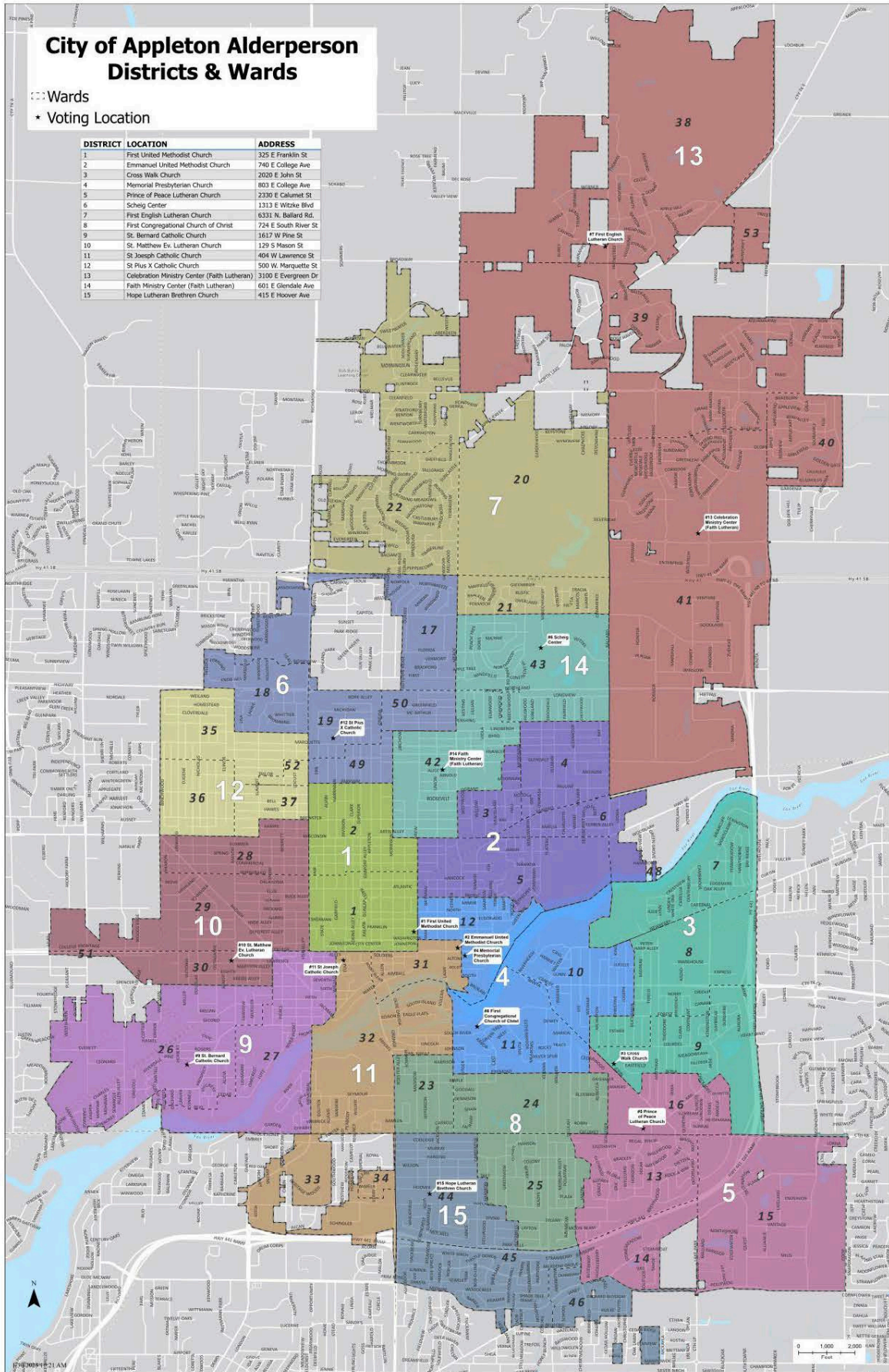
27. Do you consider yourself to be transgender?

- Yes
- No
- I'm not sure

28. Select the option which best describes your sexual orientation.

- Straight or Heterosexual
- Lesbian or Gay
- Bisexual
- Questioning
- Prefer not to answer
- Other (please specify) _____

Appendix A



28. Which neighborhood do you live in? (choose your alderperson district as seen in white numbers on the map)

Appendix A

- District 1 - Alderperson William Siebers
- District 2 - Alderperson Vered Meltzer
- District 3 - Alderperson Brad Firkus
- District 4 - Alderperson Israel Del Toro
- District 5 - Alderperson Katie Van Zeeland
- District 6 - Alderperson Denise Fenton
- District 7 - Alderperson Patrick Hayden
- District 8 - Alderperson Joss Thyssen
- District 9 - Alderperson Alex Schultz
- District 10 - Alderperson Vaya Jones
- District 11 - Alderperson Kristin Alfheim
- District 12 - Alderperson Nate Wolff
- District 13 - Alderperson Sheri Hartzheim
- District 14 - Alderperson Christopher Croatt
- District 15 - Alderperson Chad Doran
- I'm not sure
- I live somewhere else

30. My household has firearms.

- Yes
- No
- Prefer not to answer

31. The firearms in my household are stored safely.

- Yes
- No
- Prefer not to answer
- There are no firearms in my household

32. Any other comments or feedback you would like to provide?

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation



Respondents

Number of Responses: 1291

- City of Appleton Residents who Responded: 1080

Timing of Survey: March 1 – August 31, 2024

Locations advertised with banners:

- Eagle Point Senior Living Facility
- Appleton Public Library
- Appleton Downtown, Inc.
- Appleton Parks & Recreation (Dance Studio and Golf Course)
- Thompson Center on Lourdes
- Long Cheng Market

In Person Survey Support:

- Eagle Point Senior Living Facility
- Lawrence University (Campus Center and DEI Center)
- Oneida Heights Living Facility
- Salvation Army (lunch at soup kitchen)
- Riverview Gardens
- Long Cheng Market

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

Demographic Overview

Race/Ethnicity

*Respondents could
choose all that apply

Afghan	2	0.2%
African (e.g. Congolese, North African, South African)	6	0.5%
Alaskan Native	3	0.2%
Arab	4	0.3%
Asian - HMong	19	1.5%
Asian - non-HMong	25	2.0%
Black	19	1.5%
Hispanic or Latinx (e.g. Columbian, Mexican, Puerto Rican)	40	3.1%
Indian (from India)	5	0.4%
Middle Eastern	5	0.4%
Multiracial	23	1.8%
Native or Indigenous (e.g. Chippewa or Ojibwe, Ho-Chunk, Menominee, Oneida, Potawatomi)	18	1.4%
Native Hawaiiin or Pacific Islander	2	0.2%
White	1009	78.9%
Prefer not to answer	82	6.4%
Other	17	1.3%

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

Race/Ethnicity

Race/Ethnicity Appleton Census Data

Appleton population, percentage by Race		Percentage
White	62055	82.6
Black or African American	2079	2.8
American Indian and Alaska Native	358	0.5
Asian	4643	6.2
Native Hawaiian and Other Pacific Islander	67	0.1
Other Race	1181	1.6
Two or More Races	4750	6.3

7.3% of Appleton's population is Hispanic/Latino

Language Spoken at Home

Language (Select all that apply)	Count
Dari/Farsi	1
English	1155
HMong	24
Kinyarwanda	2
Spanish	38
Swahili	3
Other (Please Specify)	29

Other responses: ASL (American Sign Language), Chinese, Filipino, German, Hindi, Indonesian, Italian, Klingon, Mandarin, Menominee, Ukranian, Vietnamese

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

Household Size Breakdown (Q19)

Household Size (Including Self)	Count
1-Just Me	237
2-Me and one other person	471
3-Me and two other people	185
4-Me and three other people	156
5-Me and four other people	77
6-Me and five other people	28
7-Me and six other people	4
8-More than seven	19
Total	1177

- Largest category is households with 2 people (471)
- Many respondents are from single-person households (237)
- Outliers: Only 1 household with 10 people and 9 households with more than 10 people

Children Under 18 (Q20)

Number of Children Under 18	Count
1 Child	130
2 Children	140
3 Children	57
4 Children	21
5 Children	3
6 or more	4
None	821
Total	1176

- Most households (821) have no children under 18
- Next largest group is households with 2 children (140 responses)

Appendix B

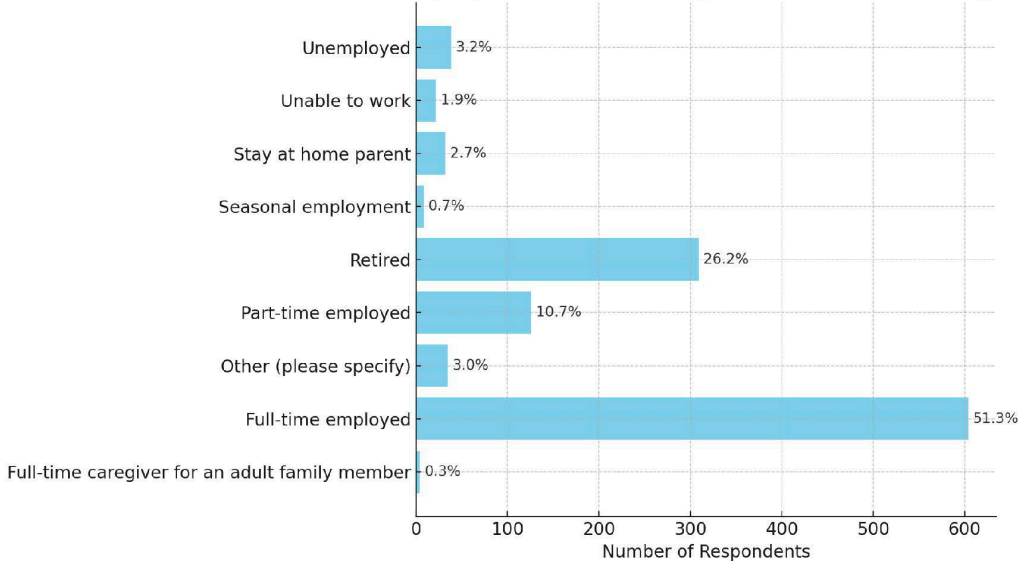
Appleton Community Concerns Survey Quadrant Analyzation

Additional Individuals Living in Household – Excluding Partner/Children (Q21)

Category	Count
Grandparent	8
Parent	26
Adult Relative	35
Youth Relative	9
Friend	21
N/A (None)	1038
Other (Please Specify)	33

- Majority report no other individuals living with them
- Those responding 'Other' specified the following: Older adult child at college, Assisted living,

Employment Status of Respondents with Percentages



- **Full-time employed** is the largest group, with 604 respondents (51.3%).
- **Retired** is the second largest group, with 309 respondents (26.2%).
- **Part-time employed** represents 126 respondents (10.7%).

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

Education Level

Highest level of education completed	Count	
Some High School	15	1.27%
High School / GED	112	9.52%
Some college	121	10.28%
Trade / technical / vocational training	78	6.63%
Associates Degree	115	9.77%
Bachelors Degree	428	36.36%
Graduate or Professional Degree	308	26.17%

•**Bachelor's Degree** holders are the largest group, making up **36.4%** (428 respondents).

•**Graduate or Professional Degrees** follow closely at **26.2%** (308 respondents).

11

Annual Household Income

Income Level	Count	Percent
Under \$15,000	64	5.6%
Between \$15,000 and \$29,999	88	7.8%
Between \$30,000 and \$49,999	157	13.8%
Between \$50,000 and \$74,999	186	16.4%
Between \$75,000 and \$99,999	176	15.5%
Between \$100,000 and \$150,000	279	24.6%
Over \$150,000	184	16.2%

Census Median Annual Household Income for City of Appleton is \$75,469

12

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

Gender

Gender (Select which best describes)	Count	Percent
Female	688	57.9%
Male	402	33.8%
Non-Binary	16	1.4%
Questioning	7	0.6%
Prefer not to say	61	5.1%
Other	14	1.2%

- Do you consider yourself to be transgender?
 - Yes: 13 respondents (1.1%)
 - No: 1148 respondents (98.0%)
 - I'm not sure: 11 respondents (0.9%)

13

Sexual Orientation

Sexual Orientation (Select which best describes)	Count	Percent
Bisexual	55	4.6%
Lesbian or Gay	43	3.6%
Questioning	12	1.0%
Straight or Heterosexual	964	81.1%
Prefer not to say	94	7.9%
Other	21	1.8%

14

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

Neighborhood / Alderperson

District	Count
1-Alderperson William Siebers	71
2-Alderperson Vered Meltzer	78
3-Alderperson Brad Firkus	52
4-Alderperson Israel Del Toro	89
5-Alderperson Katie Van Zeeland	36
6-Alderperson Denise Fenton	62
7-Alderperson Patrick Hayden	59
8-Alderperson Joss Thyssen	40
9-Alderperson Alex Schultz	66
10-Alderperson Vaya Jones	45
11-Alderperson Kristin Alfheim	49
12-Alderperson Nate Wolff	37

District	Count
13-Alderperson Sheri Hartzheim	83
14-Alderperson Christopher Croatt	86
15-Alderperson Chad Doran	44
I live somewhere else	172
I'm not sure	83

15

Survey Questions

Quadrants looking at Presence (Strongly Agree to Strongly Disagree)
and Importance (Very Important to Not at all important)

16

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

People have opportunities to receive high-quality education or skills training.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	92%	7%
Not Important or Not at all Important	1%	0%

Our community is walkable/bikeable/wheelable

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	74%	19%
Not Important or Not at all Important	6%	1%

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

Our community is walkable/bikeable/wheelable.
(By district.)

1	Agree or Strongly Agree	Disagree or Strongly Disagree	2	Agree or Strongly Agree	Disagree or Strongly Disagree	3	Agree or Strongly Agree	Disagree or Strongly Disagree	4	Agree or Strongly Agree	Disagree or Strongly Disagree	5	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	65%	30%	Important or Very Important	76%	17%	Important or Very Important	82%	8%	Important or Very Important	74%	17%	Important or Very Important	78%	11%
Not Important or Not at all Important	2%	3%	Not Important or Not at all Important	8%	0%	Not Important or Not at all Important	8%	2%	Not Important or Not at all Important	9%	0%	Not Important or Not at all Important	8%	3%
6	Agree or Strongly Agree	Disagree or Strongly Disagree	7	Agree or Strongly Agree	Disagree or Strongly Disagree	8	Agree or Strongly Agree	Disagree or Strongly Disagree	9	Agree or Strongly Agree	Disagree or Strongly Disagree	10	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	74%	19%	Important or Very Important	73%	16%	Important or Very Important	68%	26%	Important or Very Important	70%	25%	Important or Very Important	85%	11%
Not Important or Not at all Important	7%	0%	Not Important or Not at all Important	5%	5%	Not Important or Not at all Important	5%	0%	Not Important or Not at all Important	2%	3%	Not Important or Not at all Important	4%	0%
11	Agree or Strongly Agree	Disagree or Strongly Disagree	12	Agree or Strongly Agree	Disagree or Strongly Disagree	13	Agree or Strongly Agree	Disagree or Strongly Disagree	14	Agree or Strongly Agree	Disagree or Strongly Disagree	15	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	67%	24%	Important or Very Important	76%	24%	Important or Very Important	68%	21%	Important or Very Important	74%	17%	Important or Very Important	79%	14%
Not Important or Not at all Important	7%	2%	Not Important or Not at all Important	0%	0%	Not Important or Not at all Important	10%	1%	Not Important or Not at all Important	6%	2%	Not Important or Not at all Important	7%	0%

Transportation is available to people of all ages and abilities.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	69%	25%
Not Important or Not at all Important	6%	1%

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

People have enough to eat.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	64%	33%
Not Important or Not at all Important	3%	0%

Breastfeeding is promoted and supported by the community.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	47%	24%
Not Important or Not at all Important	22%	7%

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

Quality childcare is available and affordable.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	25%	66%
Not Important or Not at all Important	4%	3%

People are able to **find** jobs that support themselves and their families.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	70%	29%
Not Important or Not at all Important	1%	0%

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

People are able to **keep** jobs that support themselves and their families.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	80%	19%
Not Important or Not at all Important	1%	0%

Safe and affordable housing is available.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	36%	62%
Not Important or Not at all Important	1%	1%

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

My neighborhood is racially diverse.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	37%	31%
Not Important or Not at all Important	19%	14%

Adults refrain from abusing drugs and tobacco.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	29%	58%
Not Important or Not at all Important	4%	8%

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

Adults refrain from abusing alcohol.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	19%	67%
Not Important or Not at all Important	3%	10%

Youth do not use drugs or tobacco.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	22%	75%
Not Important or Not at all Important	1%	2%

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

Youth do not abuse alcohol.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	25%	71%
Not Important or Not at all Important	1%	3%

Schools in Appleton provide quality education.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	84%	15%
Not Important or Not at all Important	1%	0%

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

Employers do not take advantage of people who are vulnerable.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	54%	35%
Not Important or Not at all Important	8%	3%

People like me have meaningful opportunities to influence what happens in their community.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	65%	29%
Not Important or Not at all Important	3%	3%

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

Healthy foods are available and affordable.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	53%	45%
Not Important or Not at all Important	1%	1%

Children and youth are free from abuse and neglect.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	48%	51%
Not Important or Not at all Important	1%	0%

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

People are free from the threat of physical and sexual violence.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	47%	52%
Not Important or Not at all Important	1%	1%

People are treated fairly and without discrimination.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	51%	46%
Not Important or Not at all Important	2%	1%

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

Our community has a fair criminal justice system.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	75%	24%
Not Important or Not at all Important	1%	1%

Adults do not engage in aggressive or threatening behavior.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	48%	50%
Not Important or Not at all Important	2%	1%

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

Children do not engage in aggressive or threatening behavior.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	50%	47%
Not Important or Not at all Important	2%	1%

People engage in safe-sex practices.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	51%	34%
Not Important or Not at all Important	10%	4%

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

I feel that my community supports me in obtaining my health goals.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	66%	20%
Not Important or Not at all Important	9%	5%

People are free from chronic stress.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	18%	77%
Not Important or Not at all Important	1%	4%

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

Mental health challenges are recognized and treated in our community.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	52%	46%
Not Important or Not at all Important	2%	1%

Access to mental health services are available and timely.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	35%	63%
Not Important or Not at all Important	1%	1%

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

Suicide prevention resources are available and timely.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	75%	22%
Not Important or Not at all Important	2%	0%

People in Appleton enjoy a good quality of life.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	93%	6%
Not Important or Not at all Important	1%	1%

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

There are unmet mental health needs in Appleton.

**The gold standard would be that most people would disagree with this statement.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	88%	8%
Not Important or Not at all Important	1%	3%

I would use an Employee Assistance Program (EAP) to get help if needed.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	76%	9%
Not Important or Not at all Important	6%	9%

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

I would use a support program to get help if needed.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	84%	6%
Not Important or Not at all Important	5%	5%

I know where to locate mental health resources if I need them.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	69%	25%
Not Important or Not at all Important	3%	3%

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

I am comfortable getting mental health help in my community.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	73%	18%
Not Important or Not at all Important	4%	2%

Children, youth, and adults are up to date on their immunizations.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	56%	36%
Not Important or Not at all Important	5%	3%

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

Quality medical care and preventative screenings are available for all.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	61%	36%
Not Important or Not at all Important	1%	1%

Dental care and preventative screenings are available for all.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	48%	49%
Not Important or Not at all Important	2%	2%

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

People are able to effectively manage chronic diseases, such as diabetes, cardiovascular disease, and arthritis.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	55%	43%
Not Important or Not at all Important	2%	1%

Health insurance is accessible for all.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	42%	55%
Not Important or Not at all Important	2%	1%

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

I feel the cost of my health insurance limits my ability to access needed care. **The gold standard would be that most people would disagree with this statement.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	52%	43%
Not Important or Not at all Important	0%	4%

I am able to understand health insurance coverage and benefits.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	71%	26%
Not Important or Not at all Important	2%	1%

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

I feel access to health insurance and/or benefits stand in the way of me changing jobs or retiring.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	56%	31%
Not Important or Not at all Important	1%	12%

**The gold standard would be that most people would disagree with this statement.

I feel having an opportunity to access a provider who looks like me or has a shared identity with me would increase my trust in accessing health care.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	48%	11%
Not Important or Not at all Important	6%	34%

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

People in the community have adequate emotional and social support.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	52%	41%
Not Important or Not at all Important	5%	2%

I feel connected to others in my community.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	68%	19%
Not Important or Not at all Important	6%	8%

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

I feel I belong in my community.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	75%	14%
Not Important or Not at all Important	8%	4%

If I needed help, I have friends or family who could help me any time of day or night.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	85%	12%
Not Important or Not at all Important	1%	2%

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

I lack companionship.

**The gold standard would be that most people would disagree with this statement.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	18%	68%
Not Important or Not at all Important	2%	13%

I feel left out.

**The gold standard would be that most people would disagree with this statement.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	16%	64%
Not Important or Not at all Important	2%	18%

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

I feel isolated from others.

**The gold standard would be that most people would disagree with this statement.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	16%	65%
Not Important or Not at all Important	1%	17%

If I was suddenly without income for one month, I would be able to cover all my household expenses.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	70%	29%
Not Important or Not at all Important	1%	0%

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

I can pay all my bills every month.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	88%	11%
Not Important or Not at all Important	1%	0%

At the end of every month, I am able to save money.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	67%	31%
Not Important or Not at all Important	1%	1%

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

Living in Appleton is affordable.

	Agree or Strongly Agree	Disagree or Strongly Disagree
Important or Very Important	68%	30%
Not Important or Not at all Important	1%	0%

Q8) In the last 12 months, how often have you been worried that you would run out of food before you had money to buy more? (choose one)

Never	905	74.73%
Often (more than 10 times)	56	4.62%
Rarely (1-2 times)	142	11.73%
Sometimes (3-10 times)	108	8.92%

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

Q9) Does your household have enough money to pay for basic needs like food, clothing, housing, etc.?

No	58	4.78%
Sometimes	126	10.39%
Yes	1029	84.83%

Q 10) What is your living situation today? (choose one)

I do NOT have housing and I am living on the street, in a park, etc.	5	0.41%
I do NOT have housing and I am temporarily staying in a shelter.	8	0.66%
I do NOT have housing and I am temporarily staying with friends/family.	11	0.90%
I have housing and I am NOT worried about losing it.	1018	83.51%
I have housing, but I AM worried about losing it.	113	9.27%
I have housing, but it does not meet my needs.	64	5.25%

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

Q 11) Do any of the following impact your ability to keep your job or move up in your job? (Select all that apply)

Count of My ability to get job skills training	99
Count of My education level	151
Count of Availability of childcare	95
Count of Availability of respite care	25
Count of Availability of reliable transportation	67
Count of Concern for loss of benefits and/or insurance	212
Count of Job accommodations for disability	73
Count of Language barrier	14
Count of Other (please specify)	124

Can explore other (open-ended answers)
Most common themes were health issues and age/retired

Q 12) Where do you get most of your food? (choose one)

"Big Box" grocery store (Festival, Pick'n'Save, Woodman's, Aldi, Target, Walmart)	1131	92.78%
Convenience store or gas station (NOT Kwik Trip)	1	0.08%
Dollar Store (Dollar General, Family Dollar, Dollar Tree)	4	0.33%
Fast food	5	0.41%
Food pantry	6	0.49%
Kwik Trip	11	0.90%
Local ethnic markets	5	0.41%
Other (please specify)	47	3.86%
Personal garden/farm	2	0.16%
Restaurants	4	0.33%
Seasonal farmer's markets	3	0.25%

Appendix B

Appleton Community Concerns Survey Quadrant Analyzation

Q 30) My household has firearms.

No	710	60.84%
Prefer not to answer	127	10.88%
Yes	330	28.28%

Q 31) The firearms in my household are stored safely.

No	14	1.23%
Prefer not to answer	135	11.84%
There are no firearms in my household	690	60.53%
Yes	300	26.32%

Appendix C

Secondary Data

Data Year	Type	Category	Subcategory	Measures	Agegroup	Gender	Outgroup	Whitened	For Chis	Units	Details	Data Source	Hyperlink of Data Source
2020	Community Conditions	Neighborhood & Built Environment	Public Transportation	Valley Transit Riders					64,078	riders/ride	percent of high school students who agree that violence is a problem at school	Valley Transit Annual Report	https://myvalleytransit.com/wp-content/uploads/2023/02/27-Per-Street-2024.pdf
2021	Community Conditions	Neighborhood & Built Environment	Public Transportation	Valley Transit Riders					60,283	riders/ride	Ratio of women's median earnings to men's median earnings for all full-time, year-round workers (presented as "cents on the dollar")	Valley Transit Annual Report	https://myvalleytransit.com/wp-content/uploads/2023/02/27-Per-Street-2024.pdf
2022	Community Conditions	Neighborhood & Built Environment	Public Transportation	Valley Transit Riders					37,910	riders/ride	Ratio of women's median earnings to men's median earnings for all full-time, year-round workers (presented as "cents on the dollar")	Valley Transit Annual Report	https://myvalleytransit.com/wp-content/uploads/2023/02/27-Per-Street-2024.pdf
2023	Community Conditions	Neighborhood & Built Environment	Public Transportation	Valley Transit Riders					27,202	riders/ride	Ratio of women's median earnings to men's median earnings for all full-time, year-round workers (presented as "cents on the dollar")	Valley Transit Annual Report	https://myvalleytransit.com/wp-content/uploads/2023/02/27-Per-Street-2024.pdf
2024	Community Conditions	Neighborhood & Built Environment	Public Transportation	Valley Transit Riders					20,173	riders/ride	Ratio of women's median earnings to men's median earnings for all full-time, year-round workers (presented as "cents on the dollar")	Valley Transit Annual Report	https://myvalleytransit.com/wp-content/uploads/2023/02/27-Per-Street-2024.pdf
2021	Community Conditions	Social and community context	Social Connectedness	Thinking					31.67	percent	Estimated percent of households that have zero or negative net worth	Fox Valley Data Exchange	https://www.foxvalleydataexchange.com/insights/fox-valley-neighborhoods/
2022	Community Conditions	Social and community context	Social Connectedness	Thinking					0.0115	percent	Estimated percent of households that have zero or negative net worth	SN Interactive Map, QOC	https://www.sninteractive.com/
2021	Community Conditions	Social and community context	Social Connectedness	Struggling					32	percent	Estimated percent of households that have zero or negative net worth	Imagine For Crime	https://maptothink.com/data/
2021	Community Conditions	Social and community context	Social Connectedness	Suffering					45	percent	Estimated percent of households that have zero or negative net worth	Imagine For Crime	https://maptothink.com/data/
2021	Community Conditions	Social and community context	Social Connectedness	Suffering					3	percent	Estimated percent of households that have zero or negative net worth	Imagine For Crime	https://maptothink.com/data/
2023	Community Conditions	Social and community context	Safety & Violence	Safety & Violence					11	percent	Ratio of women's median earnings to men's median earnings for all full-time, year-round workers (presented as "cents on the dollar")	Whitman Department of Public Instruction, IRBS	https://qiv.wa.gov/report/yrb
2023	Community Conditions	Social and community context	Safety & Violence	Safety & Violence					15	percent	Ratio of women's median earnings to men's median earnings for all full-time, year-round workers (presented as "cents on the dollar")	Whitman Department of Public Instruction, IRBS	https://qiv.wa.gov/report/yrb
2023	Community Conditions	Social and community context	Safety & Violence	Safety & Violence					23	percent	Ratio of women's median earnings to men's median earnings for all full-time, year-round workers (presented as "cents on the dollar")	Whitman Department of Public Instruction, IRBS	https://qiv.wa.gov/report/yrb
2024 (years of data used: 2018-2023)	Community Conditions	Economic Stability	Economic Conditions	Gender Wage Gap					4/1	ratio: women's earnings / men's earnings	Estimated percent of households that are unburdened, meaning that no one in the household has a checking or savings account at a bank or credit union	County Health Rankings	https://www.countyhealthrankings.com/about
2023 (years of data used: 2016-2023)	Community Conditions	Economic Stability	Economic Conditions	Gender Wage Gap					43/1	ratio: women's earnings / men's earnings	Estimated percent of households that are unburdened, meaning that no one in the household has a checking or savings account at a bank or credit union	County Health Rankings	https://www.countyhealthrankings.com/about
2024 (years of data used: 2018-2023)	Community Conditions	Economic Stability	Economic Conditions	Gender Wage Gap					42/1	ratio: women's earnings / men's earnings	Estimated percent of households that are unburdened, meaning that no one in the household has a checking or savings account at a bank or credit union	County Health Rankings	https://www.countyhealthrankings.com/about
2021	Community Conditions	Economic Stability	Economic Conditions	Gender Wage Gap					24/1	ratio: women's earnings / men's earnings	Estimated percent of households that are unburdened, meaning that no one in the household has a checking or savings account at a bank or credit union	County Health Rankings	https://www.countyhealthrankings.com/about
2022	Community Conditions	Economic Stability	Economic Conditions	Gender Wage Gap					21/1	ratio: women's earnings / men's earnings	Estimated percent of households that are unburdened, meaning that no one in the household has a checking or savings account at a bank or credit union	County Health Rankings	https://www.countyhealthrankings.com/about
2021	Community Conditions	Economic Stability	Economic Conditions	Gender Wage Gap					3	percent	Estimated percent of households that are unburdened, meaning that no one in the household has a checking or savings account at a bank or credit union	Prosperity Now	https://scorecard.prosperitynow.org/data-by-county/financial-outcome/household-with-zero-net-worth
2023	Community Conditions	Economic Stability	Economic Conditions	Gender Wage Gap					5	percent	Estimated percent of households that are unburdened, meaning that no one in the household has a checking or savings account at a bank or credit union	Prosperity Now	https://scorecard.prosperitynow.org/data-by-county/financial-outcome/household-with-zero-net-worth
2023	Community Conditions	Economic Stability	Economic Conditions	Gender Wage Gap					7	percent	Estimated percent of households that are unburdened, meaning that no one in the household has a checking or savings account at a bank or credit union	Prosperity Now	https://scorecard.prosperitynow.org/data-by-county/financial-outcome/household-with-zero-net-worth
2023	Community Conditions	Economic Stability	Economic Conditions	Gender Wage Gap					148	dollars	Estimated percent of population with medical debt in collections	Debt in America, Urban Institute	https://debtinamerica.org/visualizations/total-debt
2023	Community Conditions	Economic Stability	Economic Conditions	Gender Wage Gap					1742	dollars	Estimated percent of population with any debt in collections	Debt in America, Urban Institute	https://debtinamerica.org/visualizations/total-debt
2023	Community Conditions	Economic Stability	Economic Conditions	Gender Wage Gap					1405	dollars	Estimated percent of population with any debt in collections	Debt in America, Urban Institute	https://debtinamerica.org/visualizations/total-debt
2023	Community Conditions	Economic Stability	Economic Conditions	Gender Wage Gap					10	percent	Estimated percent of population with any debt in collections	Debt in America, Urban Institute	https://debtinamerica.org/visualizations/total-debt
2023	Community Conditions	Economic Stability	Economic Conditions	Gender Wage Gap					13	percent	Estimated percent of population with any debt in collections	Debt in America, Urban Institute	https://debtinamerica.org/visualizations/total-debt
2021	Community Conditions	Economic Stability	Economic Conditions	Gender Wage Gap					69.2	percent	Percent of the population ages 16 and over that are in the labor force. (The labor force includes civilians who are employed or unemployed but actively seeking employment, and members of the US Armed Forces)	American Community Survey	https://data.census.gov/tables/A12C0117/2021.B23023.tn
2022	Community Conditions	Economic Stability	Economic Conditions	Gender Wage Gap					68.8	percent	Percent of the population ages 16 and over that are in the labor force. (The labor force includes civilians who are employed or unemployed but actively seeking employment, and members of the US Armed Forces)	American Community Survey	https://data.census.gov/tables/A12C0117/2021.B23023.tn
2023	Community Conditions	Economic Stability	Economic Conditions	Gender Wage Gap					67.8	percent	Percent of the population ages 16 and over that are in the labor force. (The labor force includes civilians who are employed or unemployed but actively seeking employment, and members of the US Armed Forces)	American Community Survey	https://data.census.gov/tables/A12C0117/2021.B23023.tn
2021	Community Conditions	Economic Stability	Economic Conditions	Gender Wage Gap					2.1	percent	Unemployment rate: Percent of the civilian labor force that is unemployed. (Civilians 18 years and older are classified as unemployed if they do not have a job, but were actively looking for a work during the last four weeks and are available to accept a job. The civilian labor force consists of people classified as employed or unemployed)	American Community Survey	https://data.census.gov/tables/A12C0117/2021.B23023.tn
2022	Community Conditions	Economic Stability	Economic Conditions	Gender Wage Gap					1.4	percent	Unemployment rate: Percent of the civilian labor force that is unemployed. (Civilians 18 years and older are classified as unemployed if they do not have a job, but were actively looking for a work during the last four weeks and are available to accept a job. The civilian labor force consists of people classified as employed or unemployed)	American Community Survey	https://data.census.gov/tables/A12C0117/2021.B23023.tn
2023	Community Conditions	Economic Stability	Economic Conditions	Gender Wage Gap					1.2	percent	Unemployment rate: Percent of the civilian labor force that is unemployed. (Civilians 18 years and older are classified as unemployed if they do not have a job, but were actively looking for a work during the last four weeks and are available to accept a job. The civilian labor force consists of people classified as employed or unemployed)	American Community Survey	https://data.census.gov/tables/A12C0117/2021.B23023.tn

Appendix C

Secondary Data

Year	Type	Category	Subsection	Metric/Measure	Aggregat	Claimed	Outcome	Worthiness	For Child	Units	Detail	Data Source	Hyperlink of Data
2021	Community Conditions	Education access and quality	Education	Educational attainment: graduate or postsecondary degree	0.9					Percent	Percent of population age 25 and over with each level of the following levels of educational attainment: less than high school, high school diploma or equivalent, some college or associate's degree, bachelor's degree, graduate or professional degree AP/ET/ON, METRO AHA.	American Community Survey	https://data.census.gov/tables//2021/US/00121e
2021	Community Conditions	Education access and quality	Education	High school graduate or higher	9.5					Percent	Percent of population age 25 and over with each level of the following levels of educational attainment: less than high school, high school diploma or equivalent, some college or associate's degree, bachelor's degree, graduate or professional degree AP/ET/ON, METRO AHA.	American Community Survey	https://data.census.gov/tables//2021/US/00121e
2021	Community Conditions	Education access and quality	Education	High school graduate or higher	9.5					Percent	Percent of population age 25 and over with each level of the following levels of educational attainment: less than high school, high school diploma or equivalent, some college or associate's degree, bachelor's degree, graduate or professional degree AP/ET/ON, METRO AHA.	American Community Survey	https://data.census.gov/tables//2021/US/00121e
2021	Community Conditions	Education access and quality	Education	High school graduate or higher	9.1					Percent	Percent of population age 25 and over with each level of the following levels of educational attainment: less than high school, high school diploma or equivalent, some college or associate's degree, bachelor's degree, graduate or professional degree AP/ET/ON, METRO AHA.	American Community Survey	https://data.census.gov/tables//2021/US/00121e
2021	Community Conditions	Education access and quality	Education	Bachelor's degree or higher	31.6					Percent	Percent of population age 25 and over with each level of the following levels of educational attainment: less than high school, high school diploma or equivalent, some college or associate's degree, bachelor's degree, graduate or professional degree AP/ET/ON, METRO AHA.	American Community Survey	https://data.census.gov/tables//2021/US/00121e
2021	Community Conditions	Education access and quality	Education	Bachelor's degree or higher	36					Percent	Percent of population age 25 and over with each level of the following levels of educational attainment: less than high school, high school diploma or equivalent, some college or associate's degree, bachelor's degree, graduate or professional degree AP/ET/ON, METRO AHA.	American Community Survey	https://data.census.gov/tables//2021/US/00121e
2021	Community Conditions	Education access and quality	Education	Bachelor's degree or higher	31.2					Percent	Percent of population age 25 and over with each level of the following levels of educational attainment: less than high school, high school diploma or equivalent, some college or associate's degree, bachelor's degree, graduate or professional degree AP/ET/ON, METRO AHA.	American Community Survey	https://data.census.gov/tables//2021/US/00121e
2021	Community Conditions	Education access and quality	Education	Housing cost burden (renter occupied)-0-24.9%	7.6					Percent	Percent of renter-occupied households with housing costs greater than or equal to 30 percent of monthly household income.	American Community Survey	https://data.census.gov/tables//2021/US/00121e
2021	Community Conditions	Education access and quality	Education	Housing cost burden (renter occupied)-25-34.9%	3.2					Percent	Percent of renter-occupied households with housing costs greater than or equal to 30 percent of monthly household income.	American Community Survey	https://data.census.gov/tables//2021/US/00121e
2021	Community Conditions	Education access and quality	Education	Housing cost burden (renter occupied)-35-49.9%	7.3					Percent	Percent of renter-occupied households with housing costs greater than or equal to 30 percent of monthly household income.	American Community Survey	https://data.census.gov/tables//2021/US/00121e
2021	Community Conditions	Education access and quality	Education	Housing cost burden (renter occupied)-50% or more	14.1					Percent	Percent of renter-occupied households with housing costs greater than or equal to 30 percent of monthly household income.	American Community Survey	https://data.census.gov/tables//2021/US/00121e
2020-2021	Community Conditions	Neighborhood and built environment	Neighborhood and built environment	Alcohol outlet density	997.26					per/1000 alcohol license	Percent of population with any internet subscription	WI Environmental Public Health Data Tracker	https://data.census.gov/tables//2021/US/00121e
2022	Community Conditions	Child care	Child care	Child care expenses	22	27	29			Percent	percent of population with any internet subscription	County Health Highlights and Roadmaps	https://data.census.gov/tables//2021/US/00121e
2023	Community Conditions	Child care	Child care	Child care expenses	23	29	33			Percent	percent of population with any internet subscription	County Health Highlights and Roadmaps	https://data.census.gov/tables//2021/US/00121e
2024	Community Conditions	Child care	Child care	Child care expenses	28	35	41			Percent	percent of population with any internet subscription	County Health Highlights and Roadmaps	https://data.census.gov/tables//2021/US/00121e
2022	Community Conditions	Food access and security	Food access and security	Food insecurity (children)	10.8	12.8	13.9			Percent	Estimated percent of children ages 17 and below who were food insecure during the past year	Feeding America Map the Meal Gap	https://data.census.gov/tables//2021/US/00121e
2021	Community Conditions	Food access and security	Food access and security	Food insecurity (children)	5.8	7.6	10.3			Percent	Estimated percent of children ages 17 and below who were food insecure during the past year	Feeding America Map the Meal Gap	https://data.census.gov/tables//2021/US/00121e
2020	Community Conditions	Food access and security	Food access and security	Food insecurity (children)	8.3	11	13.2			Percent	Estimated percent of children ages 17 and below who were food insecure during the past year	Feeding America Map the Meal Gap	https://data.census.gov/tables//2021/US/00121e
2019	Community Conditions	Food access and security	Food access and security	Food insecurity (children)	10.6	12.5	14.3			Percent	Estimated percent of children ages 17 and below who were food insecure during the past year	Feeding America Map the Meal Gap	https://data.census.gov/tables//2021/US/00121e
2023	Community Conditions	Internet access	Any internet access	percent of pop. with any internet subscription	93					Percent	Percent of population with any internet subscription	American Community Survey	https://data.census.gov/tables//2021/US/00121e
2023	Community Conditions	Transportation	Transportation	No vehicle available in owner occupied housing	1					Percent	Owner occupied housing: 1,040 have no vehicle available of 74,395, renter occupied housing: 2,361 have no vehicle available of 26,241 renters in the zip code area (130,041)	American Community Survey	https://data.census.gov/tables//2021/US/00121e
2023	Community Conditions	Transportation	Transportation	No vehicle available in renter occupied housing	9					Percent	Owner occupied housing: 1,040 have no vehicle available of 74,395, renter occupied housing: 2,361 have no vehicle available of 26,241 renters in the zip code area (130,041)	American Community Survey	https://data.census.gov/tables//2021/US/00121e
2022	Community Conditions	Neighborhood & Built Environment	Neighborhood & Built Environment	physical environment	47	45	44			Percent	Percent of public water supplies with fluoride content	WI DHS: Environmental Public Health Data Tracker	https://data.census.gov/tables//2021/US/00121e
2022	Community Conditions	Neighborhood & Built Environment	Neighborhood & Built Environment	physical environment	39.1	39.3	80.6			Percent	Percent of public water supplies with fluoride content	WI DHS: Environmental Public Health Data Tracker	https://data.census.gov/tables//2021/US/00121e
2022	Community Conditions	Neighborhood & Built Environment	Neighborhood & Built Environment	physical environment	0					Percent	Presence of PFAS cleanup sites presence of PFAS detected in municipal water system sampling	WI PFAS Interactive Data Viewer	https://data.census.gov/tables//2021/US/00121e
2022	Community Conditions	Neighborhood & Built Environment	Neighborhood & Built Environment	physical environment	0					Percent	Presence of PFAS cleanup sites presence of PFAS detected in municipal water system sampling	WI PFAS Interactive Data Viewer	https://data.census.gov/tables//2021/US/00121e

Appendix C

Secondary Data

Year	Type	Category	Subcategory	Measures	Applicant	Collected	Outcomes	Methodology	For Cities	Units	Points	Data Source	URL of Data Source
2022	Health Behaviors	Health Behaviors	Individuals who had received Upper Wasting	BI-Racial/ethnic, sexual					56	number of calls		Mid Year Wellness	https://mid.wisconsin.gov/annual-reports/2022/00/MidYearWellness.pdf
2023	Health Behaviors	Health Behaviors	Fire Department	Fire Inspectors Conducted	4605					number of calls		Appleton Fire Department 2023 Annual Report	https://mid.wisconsin.gov/annual-reports/2023/00/AppletonFireDepartment2023AnnualReport.pdf
2023	Health Behaviors	Health Behaviors	Fire Department	Fire Code Violations	3124					number of calls		Appleton Fire Department 2023 Annual Report	https://mid.wisconsin.gov/annual-reports/2023/00/AppletonFireDepartment2023AnnualReport.pdf
2023	Health Behaviors	Health Behaviors	Medical Behavioral Calls	Chert Mail	127					percent		Appleton Fire Department 2023 Annual Report	https://mid.wisconsin.gov/annual-reports/2023/00/AppletonFireDepartment2023AnnualReport.pdf
2023	Health Behaviors	Health Behaviors	Medical Behavioral Calls	Falls	319					percent		Appleton Fire Department 2023 Annual Report	https://mid.wisconsin.gov/annual-reports/2023/00/AppletonFireDepartment2023AnnualReport.pdf
2023	Health Behaviors	Health Behaviors	Medical Behavioral Calls	Breathing Problems	209					percent		Appleton Fire Department 2023 Annual Report	https://mid.wisconsin.gov/annual-reports/2023/00/AppletonFireDepartment2023AnnualReport.pdf
2023	Health Behaviors	Health Behaviors	Medical Behavioral Calls	Sex Person	207					percent		Appleton Fire Department 2023 Annual Report	https://mid.wisconsin.gov/annual-reports/2023/00/AppletonFireDepartment2023AnnualReport.pdf
2023	Health Behaviors	Health Behaviors	Medical Behavioral Calls	Unintended/Faring	118					percent		Appleton Fire Department 2023 Annual Report	https://mid.wisconsin.gov/annual-reports/2023/00/AppletonFireDepartment2023AnnualReport.pdf
2021	Health Behaviors	Health Behaviors	Alcohol Use	percentage of driving deaths with alcohol involvement	25	29	40			percent		Wisconsin Dept of Transportation, Fatal Analysis Reporting System	https://www.dhs.gov/transportation/fatal-analysis-reporting-system
2020	Health Behaviors	Health Behaviors	Alcohol Use	percentage of driving deaths with alcohol involvement	50	56	40			percent		Wisconsin Dept of Transportation, Fatal Analysis Reporting System	https://www.dhs.gov/transportation/fatal-analysis-reporting-system
2020	Health Behaviors	Health Behaviors	Alcohol Use	DUI arrest rates per 1,000 residents in each county	17	3.2	3.4			ratio per 1,000		Wisconsin Dept of Justice	https://www.wisconsin.gov/transportation/fatal-analysis-reporting-system
2022	Health Behaviors	Health Behaviors	Alcohol Use	DUI arrest rates per 1,000 residents in each county	2	3.1	3.1			ratio per 1,000		Wisconsin Dept of Justice	https://www.wisconsin.gov/transportation/fatal-analysis-reporting-system
2022	Health Behaviors	Health Behaviors	Alcohol Use	DUI arrest rates per 1,000 residents in each county	1.8	3.2	3.7			ratio per 1,000		Wisconsin Dept of Justice	https://www.wisconsin.gov/transportation/fatal-analysis-reporting-system
2021	Health Behaviors	Health Behaviors	Alcohol Use	Juvenile liquor law arrests in each county	4	8.2	4.1			ratio per 1,000		Wisconsin Dept of Justice	https://www.wisconsin.gov/transportation/fatal-analysis-reporting-system
2022	Health Behaviors	Health Behaviors	Alcohol Use	Juvenile liquor law arrests in each county	35	43	52			ratio per 1,000		Wisconsin Dept of Justice	https://www.wisconsin.gov/transportation/fatal-analysis-reporting-system
2023	Health Behaviors	Health Behaviors	Alcohol Use	Juvenile liquor law arrests in each county	27	80	66			ratio per 1,000		Wisconsin Dept of Justice	https://www.wisconsin.gov/transportation/fatal-analysis-reporting-system
2021	Health Behaviors	Health Behaviors	Alcohol Use	Total number of DUI arrests in each county	105	588	527			ratio per 1,000		Wisconsin Dept of Justice	https://www.wisconsin.gov/transportation/fatal-analysis-reporting-system
2022	Health Behaviors	Health Behaviors	Alcohol Use	Total number of DUI arrests in each county	94	698	359			ratio per 1,000		Wisconsin Dept of Justice	https://www.wisconsin.gov/transportation/fatal-analysis-reporting-system
2023	Health Behaviors	Mental Health	Anxiety	public school students who have experienced significant problems with anxiety in the past 12 months	40	42	43			percent		Wisconsin Department of Public Instruction, IAMS	https://qi.wisconsin.gov/ys
2021	Health Behaviors	Mental Health	Anxiety	public school students who have experienced significant problems with anxiety in the past 12 months	40	44	47			percent		Wisconsin Department of Public Instruction, IAMS	https://qi.wisconsin.gov/ys
2023	Health Behaviors	Mental Health	Depression	public school students who felt so sad or hopeless almost every day for two or more weeks in a row that they stopped usual activities in the past 12 months	22	22	28			percent		Wisconsin Department of Public Instruction, IAMS	https://qi.wisconsin.gov/ys
2021	Health Behaviors	Mental Health	Depression	public school students who felt so sad or hopeless almost every day for two or more weeks in a row that they stopped usual activities in the past 12 months	24	26	29			percent		Wisconsin Department of Public Instruction, IAMS	https://qi.wisconsin.gov/ys
2022	Health Behaviors	Mental Health	Depression	public school students who felt so sad or hopeless almost every day for two or more weeks in a row that they stopped usual activities in the past 12 months	33				45	percent		Mid Year Wellness Survey	https://mid.wisconsin.gov/annual-reports/2022/00/MidYearWellness.pdf

Appendix C

Secondary Data

Year	Type	Category	Subsection	Message	Apprent	Client	Outreach	Workshop	For Cities	Units	Details	Data Source	Hyperlink of Data Source
2022	Health Believers	Mental Health	Interventions to be in mental health treatment	black individuals					27	percent	Mind Your Wellness Survey	https://www.rockwellcenter.com/rockwellcenter/2022/05/MindYourWellness.pdf	
2022	Health Believers	Mental Health	Barriers to be in mental health treatment	white individuals					30	percent	Mind Your Wellness Survey	https://www.rockwellcenter.com/rockwellcenter/2022/05/MindYourWellness.pdf	
2022	Health Believers	Mental Health	suicidal tendencies	conducted anonymous suicide in the past 12 months					10	percent	Mind Your Wellness Survey	https://www.rockwellcenter.com/rockwellcenter/2022/05/MindYourWellness.pdf	
2022	Health Believers	Mental Health	suicidal tendencies	reported getting a suicide attempt during the past 12 months					5	percent	Mind Your Wellness Survey	https://www.rockwellcenter.com/rockwellcenter/2022/05/MindYourWellness.pdf	
2022	Health Believers	Mental Health	suicidal tendencies	LEBIC+ considered attempting suicide in the past 12 months					12	percent	Mind Your Wellness Survey	https://www.rockwellcenter.com/rockwellcenter/2022/05/MindYourWellness.pdf	
2022	Health Believers	Mental Health	suicidal tendencies	non-LEBIC+ considered attempting suicide in the past 12 months					7	percent	Mind Your Wellness Survey	https://www.rockwellcenter.com/rockwellcenter/2022/05/MindYourWellness.pdf	
2022	Health Believers	Mental Health	suicidal tendencies	LEBIC+ attempted suicide at least once in the past 12 months					3	percent	Mind Your Wellness Survey	https://www.rockwellcenter.com/rockwellcenter/2022/05/MindYourWellness.pdf	
2022	Health Believers	Mental Health	suicidal tendencies	non-LEBIC+ attempted suicide at least once in the past 12 months					6.3	percent	Mind Your Wellness Survey	https://www.rockwellcenter.com/rockwellcenter/2022/05/MindYourWellness.pdf	
2022	Health Believers	Mental Health	suicidal tendencies	people of color who have attempted suicide					1	percent	Mind Your Wellness Survey	https://www.rockwellcenter.com/rockwellcenter/2022/05/MindYourWellness.pdf	
2022	Health Believers	Mental Health	suicidal tendencies	feeling comfortable discussing mental health issues with others					5	percent	Mind Your Wellness Survey	https://www.rockwellcenter.com/rockwellcenter/2022/05/MindYourWellness.pdf	
2022	Health Believers	Mental Health	help-seeking behavior	less than 2 hours of screen time daily and reporting symptoms of anxiety					85	percent	Mind Your Wellness Survey	https://www.rockwellcenter.com/rockwellcenter/2022/05/MindYourWellness.pdf	
2022	Health Believers	Mental Health	anxiety	2-3 hours of screen time daily and reporting symptoms of anxiety					47	percent	Mind Your Wellness Survey	https://www.rockwellcenter.com/rockwellcenter/2022/05/MindYourWellness.pdf	
2022	Health Believers	Mental Health	anxiety	4-5 hours of screen time daily and reporting symptoms of anxiety					49	percent	Mind Your Wellness Survey	https://www.rockwellcenter.com/rockwellcenter/2022/05/MindYourWellness.pdf	
2022	Health Believers	Mental Health	anxiety	6+ hours of screen time daily and reporting symptoms of anxiety					62	percent	Mind Your Wellness Survey	https://www.rockwellcenter.com/rockwellcenter/2022/05/MindYourWellness.pdf	
2020	Health Believers	Sexual Activity	sexually transmitted diseases in youth	Champaign	9					cases	Wisconsin Department of Public Health Instruction, 1988	https://dhs.wisconsin.gov/sex/STIs.htm	
2021	Health Believers	Sexual Activity	sexually transmitted diseases in youth	Champaign	11					cases	Wisconsin Department of Public Health Instruction, 1988	https://dhs.wisconsin.gov/sex/STIs.htm	
2022	Health Believers	Sexual Activity	sexually transmitted diseases in youth	Champaign	30					cases	Wisconsin Department of Public Health Instruction, 1988	https://dhs.wisconsin.gov/sex/STIs.htm	
2023	Health Believers	Sexual Activity	sexually transmitted diseases in youth	Champaign	46					cases	Wisconsin Department of Public Health Instruction, 1988	https://dhs.wisconsin.gov/sex/STIs.htm	
2024	Health Believers	Sexual Activity	sexually transmitted diseases in youth	Champaign	42					cases	Wisconsin Department of Public Health Instruction, 1988	https://dhs.wisconsin.gov/sex/STIs.htm	
2020	Health Believers	Sexual Activity	sexually transmitted diseases in youth	all other STIs	11					cases	Wisconsin Department of Public Health Instruction, 1988	https://dhs.wisconsin.gov/sex/STIs.htm	
2021	Health Believers	Sexual Activity	sexually transmitted diseases in youth	all other STIs	2					cases	Wisconsin Department of Public Health Instruction, 1988	https://dhs.wisconsin.gov/sex/STIs.htm	
2022	Health Believers	Sexual Activity	sexually transmitted diseases in youth	all other STIs	7					cases	Wisconsin Department of Public Health Instruction, 1988	https://dhs.wisconsin.gov/sex/STIs.htm	
2023	Health Believers	Sexual Activity	sexually transmitted diseases in youth	all other STIs	4					cases	Wisconsin Department of Public Health Instruction, 1988	https://dhs.wisconsin.gov/sex/STIs.htm	
2024	Health Believers	Sexual Activity	sexually transmitted diseases in youth	all other STIs	3					cases	Wisconsin Department of Public Health Instruction, 1988	https://dhs.wisconsin.gov/sex/STIs.htm	
2023	Health Believers	Sexual Activity	sexually transmitted diseases in adults	Champaign	23					cases	Wisconsin Electronic Surveillance System (WESS)	https://www.wisconsin.gov/wess/	
2023	Health Believers	Sexual Activity	sexually transmitted diseases in adults	Champaign	65					cases	Wisconsin Electronic Surveillance System (WESS)	https://www.wisconsin.gov/wess/	
2023	Health Believers	Sexual Activity	sexually transmitted diseases in adults	Champaign	22					cases	Wisconsin Electronic Surveillance System (WESS)	https://www.wisconsin.gov/wess/	
2023	Health Believers	Alcohol Use	Alcohol Use	students who report they drink in the last 30 days	13				7	percent	Estimated percent of adults who report heavy drinking (defined as reporting more than 2 drinks per day on average for men and more than 1 drink per day on average for women) during the past 30 days.	Wisconsin Department of Public Health Instruction, 1988	https://dhs.wisconsin.gov/health-service-behavioral-risk-factor/
2023	Health Believers	Alcohol Use	Alcohol Use	binge drinking (students)	46				41	percent	same	Wisconsin Department of Public Health Instruction, 1988	https://dhs.wisconsin.gov/health-service-behavioral-risk-factor/
2018	Health Believers	Alcohol Use	Alcohol Use	Heavy drinking (adults) in 2018	30				31	percent	same	Wisconsin Department of Public Health Instruction, 1988	https://dhs.wisconsin.gov/health-service-behavioral-risk-factor/

Appendix C

Secondary Data

2023	2022	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998	1997	1996	1995	1994	1993	1992	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	1969	1968	1967	1966	1965	1964	1963	1962	1961	1960	1959	1958	1957	1956	1955	1954	1953	1952	1951	1950	1949	1948	1947	1946	1945	1944	1943	1942	1941	1940	1939	1938	1937	1936	1935	1934	1933	1932	1931	1930	1929	1928	1927	1926	1925	1924	1923	1922	1921	1920	1919	1918	1917	1916	1915	1914	1913	1912	1911	1910	1909	1908	1907	1906	1905	1904	1903	1902	1901	1900	1899	1898	1897	1896	1895	1894	1893	1892	1891	1890	1889	1888	1887	1886	1885	1884	1883	1882	1881	1880	1879	1878	1877	1876	1875	1874	1873	1872	1871	1870	1869	1868	1867	1866	1865	1864	1863	1862	1861	1860	1859	1858	1857	1856	1855	1854	1853	1852	1851	1850	1849	1848	1847	1846	1845	1844	1843	1842	1841	1840	1839	1838	1837	1836	1835	1834	1833	1832	1831	1830	1829	1828	1827	1826	1825	1824	1823	1822	1821	1820	1819	1818	1817	1816	1815	1814	1813	1812	1811	1810	1809	1808	1807	1806	1805	1804	1803	1802	1801	1800	1799	1798	1797	1796	1795	1794	1793	1792	1791	1790	1789	1788	1787	1786	1785	1784	1783	1782	1781	1780	1779	1778	1777	1776	1775	1774	1773	1772	1771	1770	1769	1768	1767	1766	1765	1764	1763	1762	1761	1760	1759	1758	1757	1756	1755	1754	1753	1752	1751	1750	1749	1748	1747	1746	1745	1744	1743	1742	1741	1740	1739	1738	1737	1736	1735	1734	1733	1732	1731	1730	1729	1728	1727	1726	1725	1724	1723	1722	1721	1720	1719	1718	1717	1716	1715	1714	1713	1712	1711	1710	1709	1708	1707	1706	1705	1704	1703	1702	1701	1700	1699	1698	1697	1696	1695	1694	1693	1692	1691	1690	1689	1688	1687	1686	1685	1684	1683	1682	1681	1680	1679	1678	1677	1676	1675	1674	1673	1672	1671	1670	1669	1668	1667	1666	1665	1664	1663	1662	1661	1660	1659	1658	1657	1656	1655	1654	1653	1652	1651	1650	1649	1648	1647	1646	1645	1644	1643	1642	1641	1640	1639	1638	1637	1636	1635	1634	1633	1632	1631	1630	1629	1628	1627	1626	1625	1624	1623	1622	1621	1620	1619	1618	1617	1616	1615	1614	1613	1612	1611	1610	1609	1608	1607	1606	1605	1604	1603	1602	1601	1600	1599	1598	1597	1596	1595	1594	1593	1592	1591	1590	1589	1588	1587	1586	1585	1584	1583	1582	1581	1580	1579	1578	1577	1576	1575	1574	1573	1572	1571	1570	1569	1568	1567	1566	1565	1564	1563	1562	1561	1560	1559	1558	1557	1556	1555	1554	1553	1552	1551	1550	1549	1548	1547	1546	1545	1544	1543	1542	1541	1540	1539	1538	1537	1536	1535	1534	1533	1532	1531	1530	1529	1528	1527	1526	1525	1524	1523	1522	1521	1520	1519	1518	1517	1516	1515	1514	1513	1512	1511	1510	1509	1508	1507	1506	1505	1504	1503	1502	1501	1500	1499	1498	1497	1496	1495	1494	1493	1492	1491	1490	1489	1488	1487	1486	1485	1484	1483	1482	1481	1480	1479	1478	1477	1476	1475	1474	1473	1472	1471	1470	1469	1468	1467	1466	1465	1464	1463	1462	1461	1460	1459	1458	1457	1456	1455	1454	1453	1452	1451	1450	1449	1448	1447	1446	1445	1444	1443	1442	1441	1440	1439	1438	1437	1436	1435	1434	1433	1432	1431	1430	1429	1428	1427	1426	1425	1424	1423	1422	1421	1420	1419	1418	1417	1416	1415	1414	1413	1412	1411	1410	1409	1408	1407	1406	1405	1404	1403	1402	1401	1400	1399	1398	1397	1396	1395	1394	1393	1392	1391	1390	1389	1388	1387	1386	1385	1384	1383	1382	1381	1380	1379	1378	1377	1376	1375	1374	1373	1372	1371	1370	1369	1368	1367	1366	1365	1364	1363	1362	1361	1360	1359	1358	1357	1356	1355	1354	1353	1352	1351	1350	1349	1348	1347	1346	1345	1344	1343	1342	1341	1340	1339	1338	1337	1336	1335	1334	1333	1332	1331	1330	1329	1328	1327	1326	1325	1324	1323	1322	1321	1320	1319	1318	1317	1316	1315	1314	1313	1312	1311	1310	1309	1308	1307	1306	1305	1304	1303	1302	1301	1300	1299	1298	1297	1296	1295	1294	1293	1292	1291	1290	1289	1288	1287	1286	1285	1284	1283	1282	1281	1280	1279	1278	1277	1276	1275	1274	1273	1272	1271	1270	1269	1268	1267	1266	1265	1264	1263	1262	1261	1260	1259	1258	1257	1256	1255	1254	1253	1252	1251	1250	1249	1248	1247	1246	1245	1244	1243	1242	1241	1240	1239	1238	1237	1236	1235	1234	1233	1232	1231	1230	1229	1228	1227	1226	1225	1224	1223	1222	1221	1220	1219	1218	1217	1216	1215	1214	1213	1212	1211	1210	1209	1208	1207	1206	1205	1204	1203	1202	1201	1200	1199	1198	1197	1196	1195	1194	1193	1192	1191	1190	1189	1188	1187	1186	1185	1184	1183	1182	1181	1180	1179	1178	1177	1176	1175	1174	1173	1172	1171	1170	1169	1168	1167	1166	1165	1164	1163	1162	1161	1160	1159	1158	1157	1156	1155	1154	1153	1152	1151	1150	1149	1148	1147	1146	1145	1144	1143	1142	1141	1140	1139	1138	1137	1136	1135	1134	1133	1132	1131	1130	1129	1128	1127	1126	1125	1124	1123	1122	1121	1120	1119	1118	1117	1116	1115	1114	1113	1112	1111	1110	1109	1108	1107	1106	1105	1104	1103	1102	1101	1100	1099	1098	1097	1096	1095	1094	1093	1092	1091	1090	1089	1088	1087	1086	1085	1084	1083	1082	1081	1080	1079	1078	1077	1076	1075	1074	1073	1072	1071	1070	1069	1068	1067	1066	1065	1064	1063	1062	1061	1060	1059	1058	1057	1056	1055	1054	1053	1052	1051	1050	1049	1048	1047	1046	1045	1044	1043	1042	1041	1040	1039	1038	1037	1036	1035	1034	1033	1032	1031	1030	1029	1028	1027	1026	1025	1024	1023	1022	1021	1020	1019	1018	1017	1016	1015	1014	1013	1012	1011	1010	1009	1008	1007	1006	1005	1004	1003	1002	1001	1000	999	998	997	996	995	994	993	992	991	990	989	988	987	986	985	984	983	982	981	980	979	978	977	976	975	974	973	972	971	970	969	968	967	966	965	964	963	962	961	960	959	958	957	956	955	954	953	952	951	950	949	948	947	946	945	944	943	942	941	940	939	938	937	936	935	934	933	932	931	930	929	928	927	926	925	924	923	922	921	920	919	918	917	916	915	914	913	912	911	910	909	908	907	906	905	904	903	902	901	900	899	898	897	896	895	894	893	892	891	890	889	888	887	886	885	884	883	882	881	880	879	878	877	876	875	874	873	872	871	870	869	868	867	866	865	864	863	862	861	860	859	858	857	856	855	854	853	852	851	850	849	848	847	846	845	844	843	842	841	840	839	838	837	836	835	834	833	832	831	830	829	828	827	826	825	824	823	822	821	820	819	818	817	816	815	814	813	812	811	810	809	808	807	806	805	804	803	802	801	800	799	798	797	796	795	794	793	792	791	790	789	788	787	786	785	784	783	782	781	780	779	778	777	776
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Appendix C

Secondary Data

Year	Type	Category	Subsection	Key Theme	Applicant	Calend	Outcomes	Windings	For Cities	Units	Details	Data Source	Hyper link of Data Source
2023	Health Believers	Health Believers	mental health	What is the greatest issue facing our community?	39,348					Percent	Apollon Police Dept's 2023 FBI survey	(see Apollon Police Department for data)	
2023	Health Believers	Health Believers	community engagement	What is the greatest issue facing our community?	792					Percent	Apollon Police Dept's 2023 FBI survey	(see Apollon Police Department for data)	
2023	Health Believers	Health Believers	mental health	What do you think the APD's 2024 community focus should be? (open ended)	1					rank	Apollon Police Dept's 2023 FBI survey	(see Apollon Police Department for data)	
2023	Health Believers	Health Believers	community engagement	What do you think the APD's 2024 community focus should be? (open ended)	2					rank	Apollon Police Dept's 2023 FBI survey	(see Apollon Police Department for data)	
2023	Health Believers	Health Believers	community engagement	What do you think the APD's 2024 community focus should be? (open ended)	3					rank	Apollon Police Dept's 2023 FBI survey	(see Apollon Police Department for data)	
2023	Health Believers	Health Believers	strongly agree - agree	I feel that the Apollon Police Department supports and maintains a high quality of life for its residents.	79					Percent	Apollon Police Dept's 2023 FBI survey	(see Apollon Police Department for data)	
2023	Health Believers	Health Believers	neutral	I feel that the Apollon Police Department supports and maintains a high quality of life for its residents.	17					Percent	Apollon Police Dept's 2023 FBI survey	(see Apollon Police Department for data)	
2023	Health Believers	Health Believers	disagree - strongly disagree	I feel that the Apollon Police Department supports and maintains a high quality of life for its residents.	3					Percent	Apollon Police Dept's 2023 FBI survey	(see Apollon Police Department for data)	
2020	Health Outcomes	Death	Cause of Death	All Other Codes	181					cases	Apollon Health Departments Annual Report	https://mtd.netec.com/new/reports/Document/Health/Administration/Documents/2020AnnualReport.pdf	
2021	Health Outcomes	Death	Cause of Death	All Other Codes	185					cases	Apollon Health Departments Annual Report	https://mtd.netec.com/new/reports/Document/Health/Administration/Documents/2021AnnualReport.pdf	
2022	Health Outcomes	Death	Cause of Death	All Other Codes	183					cases	Apollon Health Departments Annual Report	https://mtd.netec.com/new/reports/Document/Health/Administration/Documents/2022AnnualReport.pdf	
2023	Health Outcomes	Death	Cause of Death	All Other Codes	133					cases	Apollon Health Departments Annual Report	https://mtd.netec.com/new/reports/Document/Health/Administration/Documents/2023AnnualReport.pdf	
2024	Health Outcomes	Death	Cause of Death	All Other Codes	189					cases	Apollon Health Departments Annual Report	https://mtd.netec.com/new/reports/Document/Health/Administration/Documents/2024AnnualReport.pdf	
2020	Health Outcomes	Death	Cause of Death	Disease of the heart	139					cases	Apollon Health Departments Annual Report	https://mtd.netec.com/new/reports/Document/Health/Administration/Documents/2020AnnualReport.pdf	
2021	Health Outcomes	Death	Cause of Death	Disease of the heart	138					cases	Apollon Health Departments Annual Report	https://mtd.netec.com/new/reports/Document/Health/Administration/Documents/2021AnnualReport.pdf	
2022	Health Outcomes	Death	Cause of Death	Disease of the heart	147					cases	Apollon Health Departments Annual Report	https://mtd.netec.com/new/reports/Document/Health/Administration/Documents/2022AnnualReport.pdf	
2023	Health Outcomes	Death	Cause of Death	Disease of the heart	169					cases	Apollon Health Departments Annual Report	https://mtd.netec.com/new/reports/Document/Health/Administration/Documents/2023AnnualReport.pdf	
2024	Health Outcomes	Death	Cause of Death	Disease of the heart	182					cases	Apollon Health Departments Annual Report	https://mtd.netec.com/new/reports/Document/Health/Administration/Documents/2024AnnualReport.pdf	
2020	Health Outcomes	Death	Cause of Death	Malignant Neoplasms	148					cases	Apollon Health Departments Annual Report	https://mtd.netec.com/new/reports/Document/Health/Administration/Documents/2020AnnualReport.pdf	
2021	Health Outcomes	Death	Cause of Death	Malignant Neoplasms	154					cases	Apollon Health Departments Annual Report	https://mtd.netec.com/new/reports/Document/Health/Administration/Documents/2021AnnualReport.pdf	
2022	Health Outcomes	Death	Cause of Death	Malignant Neoplasms	161					cases	Apollon Health Departments Annual Report	https://mtd.netec.com/new/reports/Document/Health/Administration/Documents/2022AnnualReport.pdf	
2023	Health Outcomes	Death	Cause of Death	Malignant Neoplasms	134					cases	Apollon Health Departments Annual Report	https://mtd.netec.com/new/reports/Document/Health/Administration/Documents/2023AnnualReport.pdf	

Appendix C

Secondary Data

Data Year	Topic	Category	Subsection	Meta-Name	Algorithm	Column	Outage/Date	Workshop	For Docs	Units	Details	Data Source	Hyperlink of Data Source
2024	Health Outcomes	Death	Cause of Death	All Other Deaths	188					cases	Agipdon Health Department's Annual Report	https://mnd.revelcom/visualappletkewi/Document/Healthy/Administration/Document/520and/320Report/Annual%20Report%202024_AnnualReport_4.pdf	
2023	Health Outcomes	Death	Cause of Death	All Other Deaths	202					cases	Agipdon Health Department's Annual Report	https://mnd.revelcom/visualappletkewi/Document/Healthy/Administration/Document/520and/320Report/Annual%20Report%202023_AnnualReport_4.pdf	
2022	Health Outcomes	Death	Cause of Death	All Other Deaths	193					cases	Agipdon Health Department's Annual Report	https://mnd.revelcom/visualappletkewi/Document/Healthy/Administration/Document/520and/320Report/Annual%20Report%202022_AnnualReport_4.pdf	
2021	Health Outcomes	Death	Cause of Death	All Other Deaths	233					cases	Agipdon Health Department's Annual Report	https://mnd.revelcom/visualappletkewi/Document/Healthy/Administration/Document/520and/320Report/Annual%20Report%202021_AnnualReport_4.pdf	
2020	Health Outcomes	Death	Cause of Death	All Other Deaths	222					cases	Agipdon Health Department's Annual Report	https://mnd.revelcom/visualappletkewi/Document/Healthy/Administration/Document/520and/320Report/Annual%20Report%202020_AnnualReport_4.pdf	
2024	Health Outcomes	Death	Cause of Death	Cardiovascular Diseases	39					cases	Agipdon Health Department's Annual Report	https://mnd.revelcom/visualappletkewi/Document/Healthy/Administration/Document/520and/320Report/Annual%20Report%202024_AnnualReport_4.pdf	
2023	Health Outcomes	Death	Cause of Death	Chronic Lower Respiratory Diseases	30					cases	Agipdon Health Department's Annual Report	https://mnd.revelcom/visualappletkewi/Document/Healthy/Administration/Document/520and/320Report/Annual%20Report%202023_AnnualReport_4.pdf	
2022	Health Outcomes	Death	Cause of Death	COVID 19	40					cases	Agipdon Health Department's Annual Report	https://mnd.revelcom/visualappletkewi/Document/Healthy/Administration/Document/520and/320Report/Annual%20Report%202022_AnnualReport_4.pdf	
2021	Health Outcomes	Death	Cause of Death	COVID 19	64					cases	Agipdon Health Department's Annual Report	https://mnd.revelcom/visualappletkewi/Document/Healthy/Administration/Document/520and/320Report/Annual%20Report%202021_AnnualReport_4.pdf	
2020	Health Outcomes	Death	Cause of Death	COVID 19	71					cases	Agipdon Health Department's Annual Report	https://mnd.revelcom/visualappletkewi/Document/Healthy/Administration/Document/520and/320Report/Annual%20Report%202020_AnnualReport_4.pdf	
2023	Health Outcomes	Death	Cause of Death	Alzheimer Disease	40					cases	Agipdon Health Department's Annual Report	https://mnd.revelcom/visualappletkewi/Document/Healthy/Administration/Document/520and/320Report/Annual%20Report%202023_AnnualReport_4.pdf	
2022	Health Outcomes	Death	Cause of Death	Alzheimer Disease	35					cases	Agipdon Health Department's Annual Report	https://mnd.revelcom/visualappletkewi/Document/Healthy/Administration/Document/520and/320Report/Annual%20Report%202022_AnnualReport_4.pdf	
2021	Health Outcomes	Death	Cause of Death	Alzheimer Disease	37					cases	Agipdon Health Department's Annual Report	https://mnd.revelcom/visualappletkewi/Document/Healthy/Administration/Document/520and/320Report/Annual%20Report%202021_AnnualReport_4.pdf	
2020	Health Outcomes	Death	Cause of Death	Accident (unintentional injury)	32					cases	Agipdon Health Department's Annual Report	https://mnd.revelcom/visualappletkewi/Document/Healthy/Administration/Document/520and/320Report/Annual%20Report%202020_AnnualReport_4.pdf	
2023	Health Outcomes	Death	Cause of Death	Accident (unintentional injury)	34					cases	Agipdon Health Department's Annual Report	https://mnd.revelcom/visualappletkewi/Document/Healthy/Administration/Document/520and/320Report/Annual%20Report%202023_AnnualReport_4.pdf	
2022	Health Outcomes	Death	Cause of Death	Accident (unintentional injury)	37					cases	Agipdon Health Department's Annual Report	https://mnd.revelcom/visualappletkewi/Document/Healthy/Administration/Document/520and/320Report/Annual%20Report%202022_AnnualReport_4.pdf	
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2020	Health Outcomes	Death	Cause of Death	Accident (unintentional injury)	33					cases	Agipdon Health Department's Annual Report	https://mnd.revelcom/visualappletkewi/Document/Healthy/Administration/Document/520and/320Report/Annual%20Report%202020_AnnualReport_4.pdf	

Community Health Report

2025



TRI-COUNTY
COMMUNITY HEALTH
IMPROVEMENT
COALITION

Tri-County Community Health Improvement Coalition



Table Of Contents

Letter to the Community	3
Demographics of the Tri-County	4
Key Takeaways & Our Capacity	5
Vital Conditions Framework	6
Belonging & Civic Muscle	8
Meaningful Work & Wealth	12
Humane Housing	16
Basic Needs for Health & Safety	20
Lifelong Learning	26
Reliable Transportation	30
Thriving Natural World	35
Health Behaviors	41
Health Outcomes	45
Assessment Results - Purpose & Process	48
Collaboration & Next Steps	49
Thank You	50
References	51

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Submitted to Coalition membership for publication approval November 18th, 2025.

Published January 28th, 2026.

Letter To The Community

This report marks the first time that the Tri-County Region of Calumet, Outagamie, and Winnebago Counties has engaged in a singular process to produce a shared Community Health Needs Assessment. Facing distinctive organizational deadlines, differing regulatory requirements, unique histories with community involvement, and varied experience with tools/models for engaging in this work, our five local public health agencies and four area health systems bravely stepped into the messy work of “starting somewhere”.

Despite the challenges, we agreed on this shared purpose: to improve health and well-being for every individual in our communities. With this focus, we voted to adopt a common, shared tool: Mobilizing for Action through Planning and Partnerships 2.0 (MAPP 2.0). We invited community nonprofit agencies to share decision-making power and grow the coalition’s reach and representation, and we completed one cycle of the Needs Assessment/Health Improvement Plan process together.

With the north star of shared purpose and the goal of crossing the finish line together - no matter how “messy” – this report was created to best serve the people and communities of the Tri-County Region. We know this work takes time, and we have just begun to dip our toe into true collaboration – especially with our community partners outside of public health and health systems. It will require deep listening, relationship building, power sharing, and trust. It means working through challenges and designing solutions that work for all.

At a time when the world feels increasingly fragmented, we in the Tri-County Region are coming together. We are choosing to build a coalition of public health, health systems, and community representatives that care about creating a future where every person can thrive physically, mentally, emotionally, and socially. In the spirit of this coming together, we make this promise... to invest our time, energy, and resources to keep evolving this collaborative process and building authentic engagement with the community.

The information captured in this report reflects data about community conditions, diverse voices that bring the data to life, and perspectives that help frame the community’s most pressing needs. Next comes the work of responding, as individuals, organizations, and a coalition, through collaboration, alignment, and action.

We invite you to join us. Together, we can take these first steps to “start somewhere” on the road to community health and well-being.

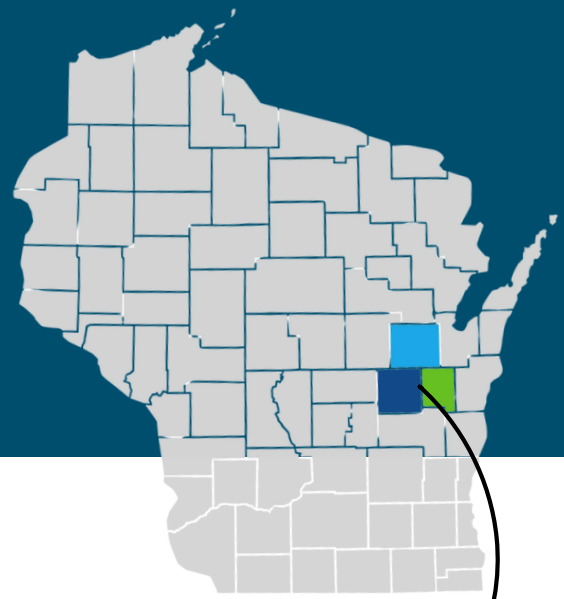
With appreciation and commitment,

Ascension
Aurora Health Care
Calumet County Public Health
Casa Hispana
Children’s Wisconsin
City of Appleton Health Department
City of Menasha Health Department
Diverse and Resilient
Fox Valley Data Exchange
Hmong American Partnership Fox Valley

NEW Hmong Professionals
NEW Mental Health Connection
Outagamie County Public Health
Partnership Community Health Center
People of Progression
Samaritan Fox Valley
ThedaCare
United Way Fox Cities
Winnebago County Public Health
YMCA of the Fox Cities

Who We Are

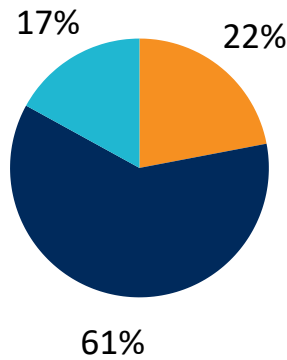
The Tri-County includes Calumet, Outagamie, and Winnebago counties in Northeast Wisconsin.



Population By Age

Each county has approximately the same population percentages by age.

- Under 18
- 18-64
- 65 and over

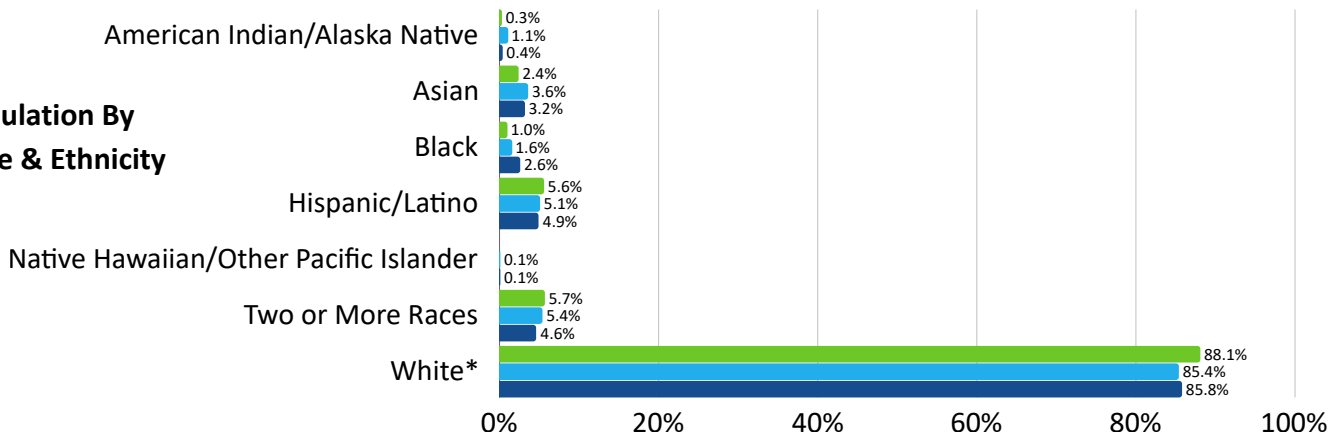


Total Population

Calumet	53,602
Outagamie	195,390
Winnebago	173,307

Population By Race & Ethnicity

- Calumet
- Outagamie
- Winnebago



*Non-Hispanic

(ACS Table B01001, 2023 5-year est.)

Languages Spoken

Calumet

English, Spanish, Hmong

Outagamie

English, Spanish, Hmong, Swahili, Dari, Kinyarwanda, and Lingala

Winnebago

English, Spanish, Swahili, Hmong

(Internal Counts of WIC Translation Services)

Key Takeaways & Our Capacity

Key Takeaways

This report emphasizes a driving force behind differences in health outcomes: wealth inequality. Through rigorous root cause analysis and data exploration, wealth inequality was consistently a dominant factor influencing health outcomes. While other demographic factors - like race or sexuality - also display relationships with health conditions, these characteristics are rarely inherently tied to health. Instead, social systems and power dynamics that privilege certain demographic groups serve to generate differences in health outcomes. In contrast, wealth inherently determines whether an individual has access to food, health care, housing, child care, and more. It dictates whether an individual's basic needs are met, and greater wealth consistently leads to better health outcomes. The narrative in this report seeks to highlight the outsized role wealth plays in accessing the resources and services necessary to lead healthy lives.

There is one component of health that has a notably weaker relationship with wealth: mental well-being. While the stresses of poverty or a lack of shelter can certainly harm an individual's mental health, mental health conditions can afflict anyone. Protective factors like strong interpersonal relationships, a sense of belonging, access to behavioral health care providers, regular physical activity, and adequate sleep can all improve one's mental health status. Mental health conditions can serve as both causes and effects of many of the health conditions listed in this report, and are an essential part of a person's overall well-being.

Our Capacity

A Community Health Assessment serves primarily to do three things: identify the health status of a community, determine the root causes of health conditions, and guide future interventions to improve the health of a community.

As stated above, wealth inequality is the root cause of many health disparities in the Tri-County region. However, Public Health has limited financial resources and minimal political influence to meaningfully address wealth inequality. Currently, both the federal government and the State of Wisconsin have also reduced funding for local grant opportunities. Therefore, the strength of this coalition will not derive from its financial power. Instead, this coalition derives its strength from its ability to coordinate community partner efforts to effect change. It will rely on collective vision, local advocacy, and intentional collaboration. And it may require prioritizing other upstream factors that influence health outcomes.

Technical Note

At the time this document was completed, the federal government shutdown of October-November 2025 had made Census Bureau information, both current and historical, inaccessible. There are some data points we intended to include in this report - for instance, the proportion of the population that is uninsured - that we would typically source from the Census Bureau. Because we had not yet pulled these data at the beginning of the shutdown, we have been obligated to omit them from this report or to seek other sources that may not be as reliable as the Census Bureau. Please visit the Census Bureau website when it is operational again for accurate data.

Vital Conditions Framework

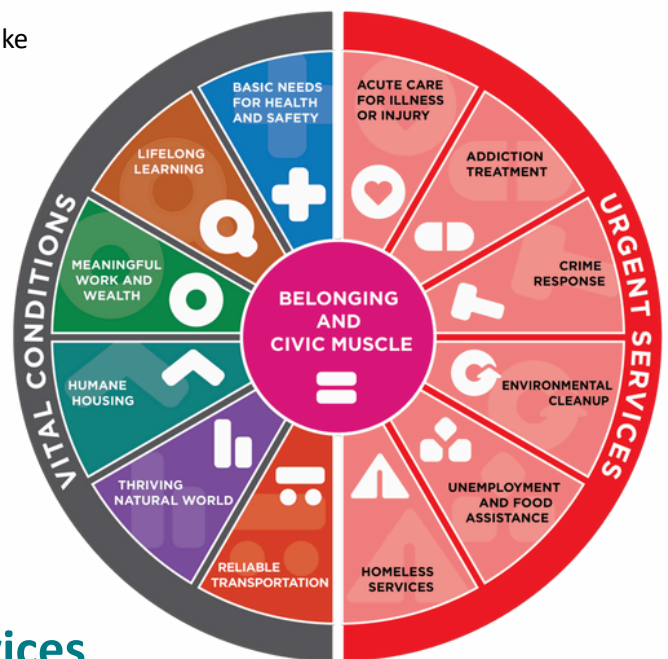
Nearly 500,000 people live in Calumet, Outagamie, and Winnebago Counties, a region in northeast Wisconsin covering more than 1500 square miles. The Tri-County is rich in resources, including Fortune 500 companies, top-ranking schools and universities, outdoor recreation for every season, and an abundance of arts and culture (New North, Inc.). A few cities in the Tri-County have even been hailed as top places to live in the country.

This document is the inaugural Community Health Needs Assessment for the Tri-County. Previous health assessments were defined by a city or county jurisdiction or a healthcare service area. While programs and services are often restricted by jurisdictional boundaries, many of us cross county lines without even thinking about it. We might have a favorite supper club in Winneconne or Hortonville, or enjoy an afternoon at High Cliff State Park. Our doctor might be in Appleton, our dentist in Neenah, yet we might live in Menasha or Fox Crossing.

Vital Conditions for Health and Well-being

Thriving communities have certain characteristics that make them desirable places to live. These characteristics can be described as Vital Conditions for Health and Well-being.

“Vital conditions are the properties of places and institutions that we all need all the time to reach our full potential. They include physical necessities like food, water, and humane housing, but also include things that are harder to quantify, like a sense of belonging and agency or civic muscle. Investments in these conditions are necessary to create an equitable, thriving future for ourselves and for generations to come” (The Rippel Foundation).



Vital Conditions vs Urgent Services

Urgent services are broadly defined as all of the services that anyone under adversity would need to temporarily regain or restore their health and well-being. These include everything from urgent care clinics to food pantries and homeless shelters. Urgent services are necessary for a safe, healthy, and thriving community (The Rippel Foundation).

Thriving For All

The Tri-County Community Health Improvement Coalition believes we have the resources and capacity for all community members to thrive, no exceptions.

Each vital condition is distinct and indispensable. Together, they form an interdependent system that shapes opportunities for people and places to thrive. If any vital condition is denied or otherwise unfulfilled, serious adversity can accumulate, revealing itself in excess rates of illness, unemployment, housing distress, food insecurity, loneliness, and more.



Belonging & Civic Muscle

Sense of shared community and power to shape a common world



Meaningful Work & Wealth

Rewarding and diverse jobs/careers that provide a reasonable standard of living



Humane Housing

Adequate, affordable living space in the community where we live



Basic Needs for Health & Safety

Access to affordable food, health care, and other necessities



Lifelong Learning

Affordable child care and educational opportunities



Reliable Transportation

Affordable and diverse options to reach community spaces where we live our lives



Thriving Natural World

Sustainable resources, integration with nature, freedom from hazards

Belonging & Civic Muscle



Most people recognize the feeling of belonging or not belonging within a certain group, physical places, and experiences. Belonging is a feeling of happiness, comfort, security, being accepted, and included. Belonging is affected by many factors, making it a challenge to assess. Simply put, you know it when it's there and when it's missing.

Belonging is important because it's a **fundamental human need**, just like food, water, and safety. People are wired to seek **connection and acceptance**.

- For individuals, belonging:
 - Supports mental health by reducing loneliness, anxiety, and depression (CDC).
 - Provides motivation and resilience, since people are more willing to take risks, learn, and persist when they feel supported.
- For groups and organizations, belonging:
 - Increases trust, cooperation, and collaboration.
 - Strengthens retention and engagement in schools, workplaces, and communities.
 - Fosters innovation, because people share more openly when they feel safe and respected.

Belonging is often the result of strong social connections. When people experience meaningful and positive relationships, they feel a sense of inclusion and attachment to their social groups or communities, fulfilling their need for belonging. **Lacking social connection can increase the risk for disease and negative health outcomes** including heart disease, stroke, anxiety, depression, and dementia (Office of the U.S. Surgeon General).

High school student data



1 out of 3 high school students in the Tri-County area said they felt like they didn't belong at school. Students who were:

Food Insecure, Female, LGBT, People of Color, or People with Physical Disabilities

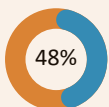
were much more likely to report feeling like they didn't belong.



3 out of 4 high school students don't get emotional support when needed.

(WI DPI YRBS, 2023)

Adult survey data



Less than half of adults in the Tri-County region feel a strong or very strong sense of community belonging.

(Imagine Fox Cities Survey, 2021)



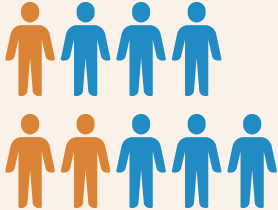
1 out of 5 adults does not get the social and emotional support they need.

(BRFSS, 2023)

Belonging & Civic Muscle



Recent data show that the United States is in a mental health crisis, experienced by people of all ages—but especially by young people. This trend was observed before the COVID-19 pandemic but has been worsened by pandemic-related factors (CDC).



1 out of 4 high school students in the Tri-County area feel persistently sad or hopeless.

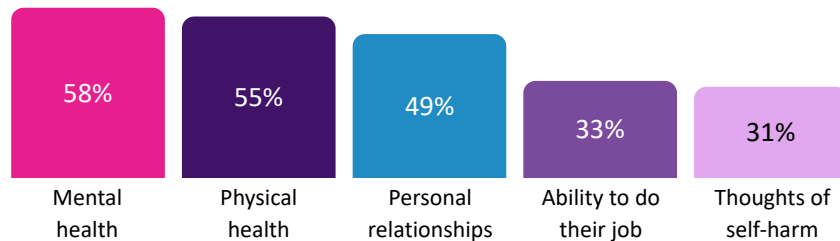
2 out of 5 high school students in the Tri-County area reported problems with anxiety.

(WI DPI YRBS, 2023)

Social connection is a strong predictor of mental health and physical health. People who feel isolated experience higher incidence of anxiety, depression, chronic pain, and thoughts of suicide.



Among the 22% in the US reporting loneliness or isolation, many say it negatively impacts their:



(Mental Health & Suicide Prevention Recommendations, 2023)

People of color and LGBTQ+ community members experience the most isolation and the least amount of acceptance. In order for social connection to be experienced by all, it will require an open-mindedness to achieve a deeper understanding and unconditional positive regard for all human beings.

People of color and LGBTQ+ individuals are more than twice as likely to feel isolated, according to the Mind Your Wellness Survey (MYWS) respondents (2022).

1 in 10 MYWS respondents reported considering suicide in the past year.

- **LGBTQ+ folks are 11 times more likely to have attempted suicide than non-LGBTQ.**
- **People of color are 3 times more likely to have attempted suicide than whites.**

It's essential to recognize that feeling connected and having a sense of belonging are powerful safeguards against suicide and poor mental health.

“Being socially connected is the brain’s lifelong passion. It’s been baked into our operating system for tens of millions of years.” (Dr. Matthew Lieberman, UCLA neuroscientist)

Belonging & Civic Muscle



Civic muscle is about being part of a community and contributing to its vibrancy. It includes things like voting, volunteering, and community voice. How we embrace human rights, injustice, civil discourse, and conflicts are questions to consider in an effort to build civic muscle.

Our community, our health

70% of our health is the result of where we live, learn, work, and play. Everything, from schools and libraries to businesses and banks, road conditions, bike lanes, housing options, grocery stores, recreational opportunities, spiritual offerings, green space, parks, trees, plants, and pollinators, factors into our health.

Our communities (and how well they function) play a much larger role in our health than individual choice.

To improve health, focus on belonging:

Belonging means having a meaningful voice and the opportunity to participate in the design of political, social, and cultural structures that shape one's life — the right to both contribute and make demands upon society and political institutions (Othering & Belonging Institute).

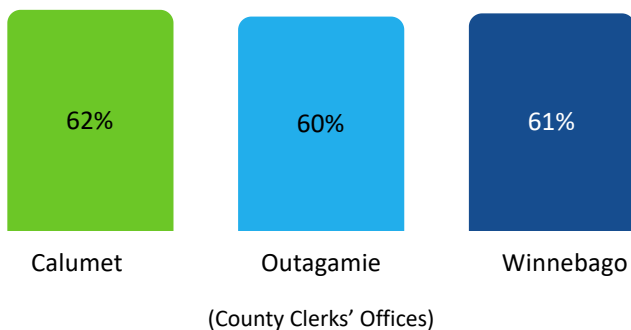
To improve belonging, focus on civic muscle

The people elected to local, state, and federal offices are responsible for making policies that directly affect our health. Policies include clean water and air regulations, Medicaid eligibility, and protections against harmful substances such as tobacco and nicotine products. Elected officials have the power to control the outsized influence of corporations. Without regulations, some corporations have shown their willingness to pollute our environment, make ultra-processed food with little nutritional value, underpay our workers, and lobby to keep it all in place.

These are **Commercial Determinants of Health**, or the ways corporate power shows up in every corner of our lives, from the food we eat to the air we breathe to the policies that govern our communities.

Impacted citizens are often the ones to sound the alarm about calculated corporate strategies that increase profit yet cause harm. Unjust corporate decisions move ahead until enough alarms go off.

Percent of registered voters who voted
in the April 1, 2025 election



Civic participation helps us care for our family, our community, and one another.

Openness to others, to different opinions, to our future, and to have hope is necessary. We can support one another to participate in civic activities, like voting in local, state, and national elections, attending town hall meetings, volunteering for local projects, joining community groups, and speaking out on important issues.

Belonging & Civic Muscle



The Importance of Belonging and Civic Muscle

Do our communities have a strong history of citizen-led action and community engagement? How feasible is it to influence local decisions? Communities where people do not feel valued experience high levels of apathy. Residents and the community itself suffer. People who know their voices will be heard in the process of shaping their community's future make better, healthier choices. People with a strong sense of efficacy, belonging, and social connectedness tend to live healthier, happier lives.

Problem Today: Weak Civic Muscle

A lack of "civic muscle," or the capacity for collective action and community problem-solving, stems from factors like political polarization and hyperpartisanship, decreased trust in institutions, a decline in the number and vibrancy of community organizations, and insufficient civic education and opportunities for dialogue (Roulier).

Lack of Trust

Americans' trust in the federal government, historically respected institutions, education, science, public health, and media is at historic lows (Transparency International).

Systemic Barriers

Indicators around voter turnout, voter suppression, and systemic inequalities can create significant barriers to civic participation.

Apathy

When citizens feel like their voices don't matter, or they lack the time and knowledge to participate effectively, apathy and disengagement can occur.

Corruption

Corruption is the abuse of entrusted power for private gain. Corruption erodes trust, weakens democracy, hampers economic development, and further exacerbates inequality, poverty, and social division. It can happen anywhere: businesses, government, the courts, media, sports, financial systems, education, and health care. It can involve anyone: politicians, government officials, public servants, business leaders, or members of the public.

The larger impact of weakened civic muscle is that it creates an opening for a small group to dominate decision-making that can neglect the broader community interests and needs.

Where Do We Go Next?

Opportunities to Improve Belonging & Civic Muscle

- Cultivate community participation and leadership
- Support corporate social responsibility
- Prioritize inclusive community over corporate interests
- Build public-private partnerships
- Support organizations like People of Progression, Diverse and Resilient, NEW HMong, Casa Hispana, and more
- Resist the rise of hate and dismantle systemic oppression and racism

Meaningful Work & Wealth

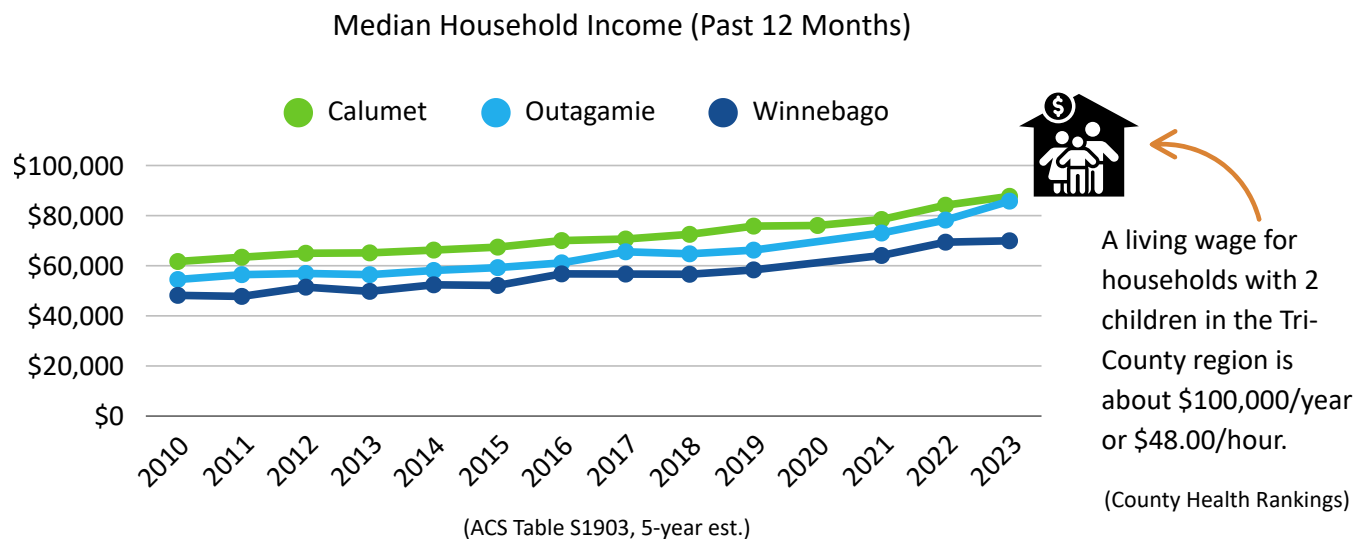


Our lives and self-worth flourish when doing productive, rewarding work. The ability to accumulate adequate wealth shapes the living standards not only for families and communities, but for generations to come.

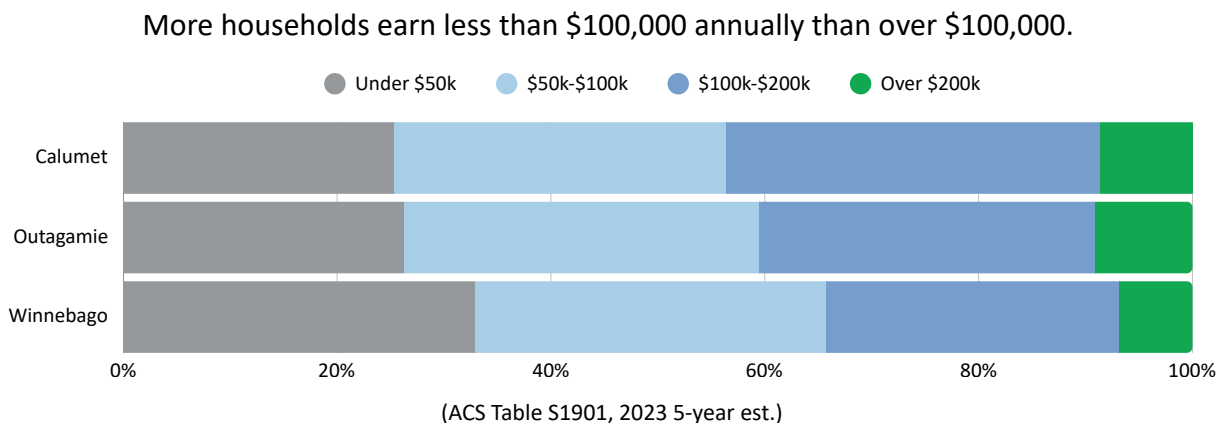
Limited income has a significant impact on access to quality housing, food, transportation, education, and health care. People living with financial strains have:

- Poorer self-reported health
- More stress, increased risk for self-harm, suicide attempts, depression, and anxiety
- Higher rates of chronic and communicable disease













Because income is a significant, well-documented determinant of health, the effects of low income and income inequality are reflected in population health. There has been a significant increase in income inequality in the United States since the 1980s, following deliberate government policies to reduce tax rates and shrink social safety net programs (Avanceña et al.).



Median income is the midpoint of income distribution, where half of all households had an annual income below this amount, and half had annual incomes above it.



Meaningful Work & Wealth

Category	Survival \$	Stability \$
 Housing	\$1,065	\$1,861
 Transportation	\$935	\$1,517
 Childcare	\$1,557	\$1,961
 Food	\$1,293	\$2,078
 Technology	\$116	\$116
 Miscellaneous	\$558	\$822
 Healthcare	\$617	\$688
 Tax Payments	\$627	\$1,351
 Savings	\$0	\$822
 Monthly Total	\$6,768	\$11,216
 Annual Total	\$81,216	\$134,592
 Hourly Wage/Adult	\$20.31	\$33.65

ALICE Households: Essential, Working, Struggling

ALICE is an acronym for:

Asset Limited, Income Constrained, Employed

ALICE households are experiencing financial hardship. They earn above the Federal Poverty Level (FPL) yet struggle to afford basic needs. For a growing number of households, financial stability is out of reach, no matter how hard they work.

A comparison of **estimated monthly costs** for **Survival** and **Stability budgets** for a family of four living in the Tri-County with two working adults and two children in childcare illustrates the importance of a living wage.

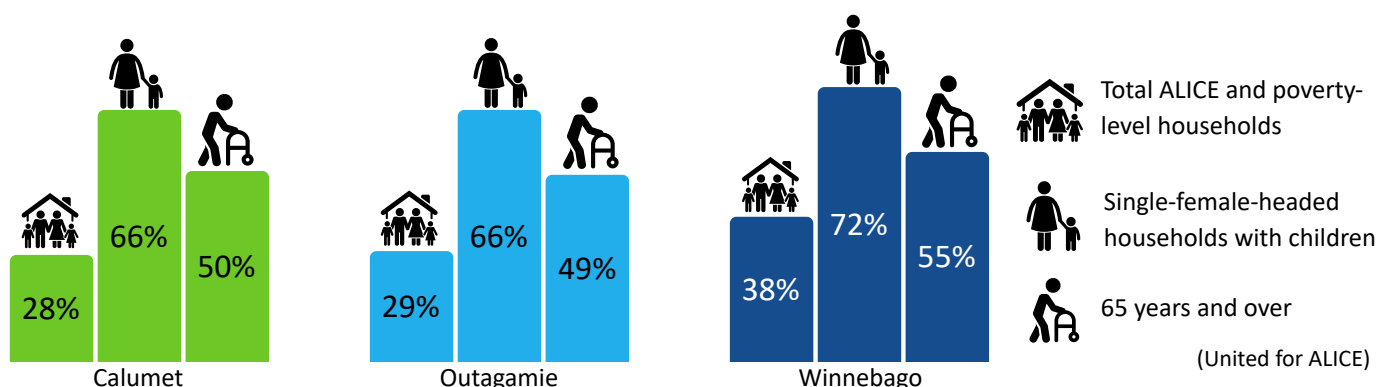
The Survival budget is the minimum cost to live and work in today's economy. The Stability budget shows how more income provides a more financially stable household, including the ability to save for future needs.

Data reports use a standardized set of measurements to quantify the cost of a basic household budget in each county in each state, and to show how many households are struggling to afford it.

United for ALICE has developed measures that provide a comprehensive, unbiased picture of financial hardship. **In the US, 41% of households cannot make ends meet.**

Household budget calculators from United for ALICE Calumet, Outagamie, & Winnebago Counties.

Single-female-headed households with children and people 65 and older are disproportionately ALICE households.



Meaningful Work & Wealth



Income Inequality

The income gap between the rich and everyone else has been growing by every major statistical measure for more than 30 years.

- Low wage earners have not seen wage growth as compared to high wage earners
- White and Asian wages are higher than Black and Latino wages
- Corporations that pay the lowest median wages reward CEOs through stock buy-backs:
 - Lowe's
 - Home Depot
 - Walmart
 - Autozone
 - Target
 - Dollar General
- Women are underrepresented in high-level, highly paid positions and overrepresented in low-paying jobs.
- Women of color and transgender individuals experience higher levels of poverty, unemployment, and other economic hardship (Inequality.org).



Working now, highest paying job \$13/hr.

Difficult to get a job because of disability.



\$37
2021



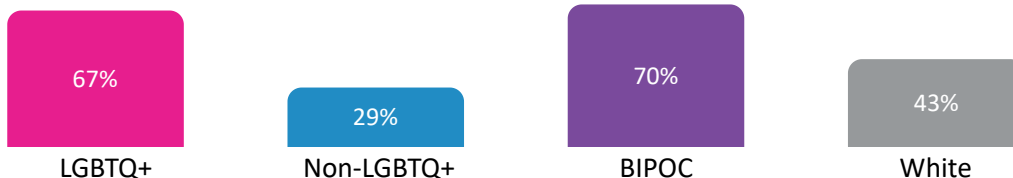
\$48
2023

In the Tri-County, the hourly wage needed to cover basic expenses for 1 adult and 2 children increased by about \$10 over 2 years.

(County Health Rankings)

Tri-County Wage Gaps

Annual Household Income Under \$50,000



(Mind Your Wellness Survey, 2023)

Cuts to vital food and housing programs risk unraveling a tightly linked support structure that strengthens the fabric of our communities.

Across the country, rising food and housing costs are pushing families to the brink—while critical resources are being pulled away. Recent and pending federal cuts to vital nutrition and housing programs threaten to deepen the crisis, undermining not just individual stability but the strength and resilience of entire communities (Robert Wood Johnson Foundation).

Meaningful Work & Wealth



How Did We Get Here?

The US system prioritizes capital over labor. Corporate profits flow mostly to shareholders, executives, and investors, while workers' bargaining power and wage growth have been weakened by policy choices and shifts in business norms.

- Since the 1970s, worker productivity in the US has risen, but wages have not kept pace (United for ALICE).
- Unions are in decline. At its peak in 1954, about 33% of workers were in a union, whereas today it's closer to 10%.
- Since the 1980s, corporate governance has emphasized maximizing shareholder value above other goals (Posner).
- The US minimum wage has not kept up with inflation. Today's minimum wage is \$7.25/hour. It should be well above \$20.00/hour (Romero and Whittaker).
- Corporate tax cuts (especially in 2017) have increased after-tax profits.
- Income inequality has skyrocketed. Over the past three decades, America's most affluent families have added to their net worth, while those on the bottom have dipped into "negative wealth," meaning the value of their debts exceeds the value of their assets, according to National Bureau of Economic Research data (Inequality.org).

The Shrinking Middle Class

The share of American adults who live in middle-income households has decreased from 61% in 1971 to 51% in 2023. This downsizing has proceeded slowly but surely for the last fifty years, with each decade ending with fewer adults living in middle-income households than at the beginning of the decade (Kochhar and Sechopoulos).

- Among Americans ages 25 and older in 2022, 52% with a bachelor's degree or higher level of education lived in middle-class households, and another 35% lived in upper-income households.
- Married adults and those in multi-earner households made more progress on the income ladder from 1971-2021.
 - Unmarried men and women were much more likely to be in the lower-income tier in 2021. Unmarried men are less likely than unmarried women to be lower income.
- Despite progress, Black and Hispanic adults trail behind other groups in their economic status.

Where Do We Go Next?

First, we need to understand the connection between wealth and health. Many health outcomes, from life expectancy to infant mortality and obesity, can be linked to economic inequality within a population (Inequality.org). Greater income inequality within a population can negatively impact even the health of the wealthy. This is primarily because greater inequality reduces the sense of shared community, which leads to more mistrust and insecurity for all.

Attributes of a thriving community are evident in policies that support people throughout the lifespan, such as affordable child care, livable wages for caregivers, free and healthy school breakfast and lunches, affordable health insurance, paid family leave, access to post-secondary education, well-paying jobs, and job training programs. Local organizations like LEAVEN Fox Cities, Vida, ADVOCAP, and Goodwill NCW are already helping stabilize local residents' finances and lift them out of poverty.

Humane Housing



Humane Housing is about stable, safe places to live. It's creating communities where people can thrive. Explore the data below to find out where our communities are succeeding and where there is room for improvement.

Many community members are actively seeking help for housing needs.

- Rent has been stable for more than a decade in the Tri-County area.
 - It is difficult for families with children to find affordable vacancies.
 - Renters are more likely to be young, poor, and/or BIPOC (Black, Indigenous, and People of Color).
- Home ownership is the best way for families to accumulate wealth in America.
 - The cost of buying a home has risen faster than wages since 2021, after the height of the COVID-19 pandemic.
 - This makes existing disparities even worse.
- To solve this crisis, we need to build more housing supply.
 - Single-family zoning regulations and high interest rates make it harder for builders to build new housing, and harder for current homeowners to move out of their home.



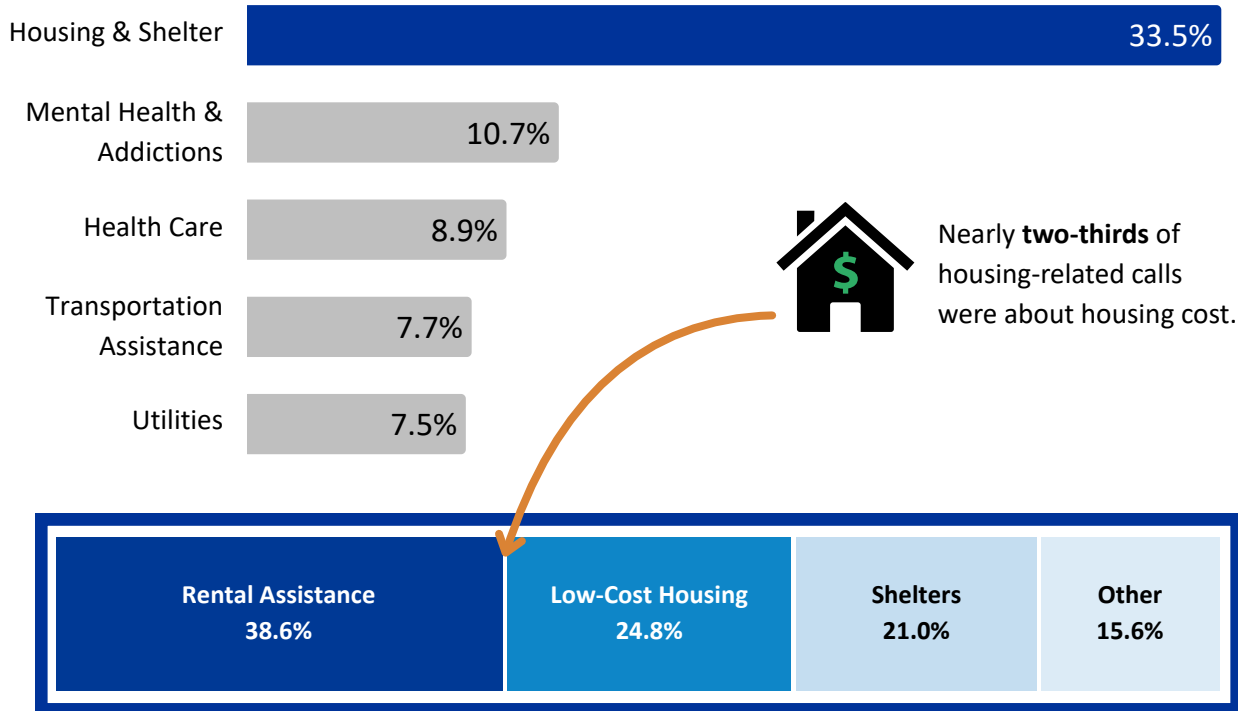
I am very concerned about the lack of affordable housing in this area.

This is a wonderful community...

However, spending even 5 minutes searching for rentals and homes leaves almost nothing relatively affordable.



Housing and shelter requests were the **most common topic** for United Way 211 from July 29, 2024, to July 28, 2025.



Nearly **two-thirds** of housing-related calls were about housing cost.

(211 Counts - Calumet/Outagamie/Winnebago Co. aggregate calls)

Humane Housing



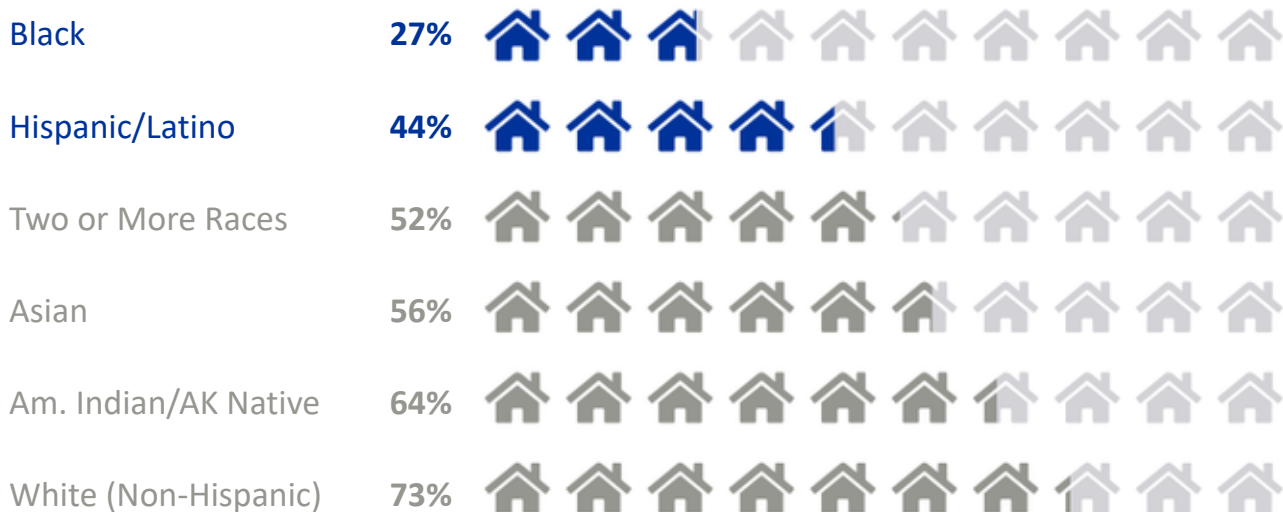
1 out of 3 Renters is spending 30% or more of their income on housing costs versus **1 out of 7 Homeowners**

(ACS Table B25140, 2023 5-year est.)

Housing Cost Burden is a real problem in our community.

- Housing Cost Burden is when a household spends **more than 30%** of their gross annual income on housing costs.
 - Families experiencing Housing Cost Burden are less likely to be able to afford basic needs like food, health care, and child care.
 - Housing Cost Burden is associated with worse physical, mental, and financial health.
- Renters in the Tri-County region are much more likely to experience Housing Cost Burden.
 - This means renters have a harder time saving money to prepare for emergencies or to plan their future.
 - Renters are more likely to be young, poor, and/or BIPOC.

Less than half of **Black and Hispanic/Latino** households own their home.



(ACS Table B25003, 2023 5-year est.)

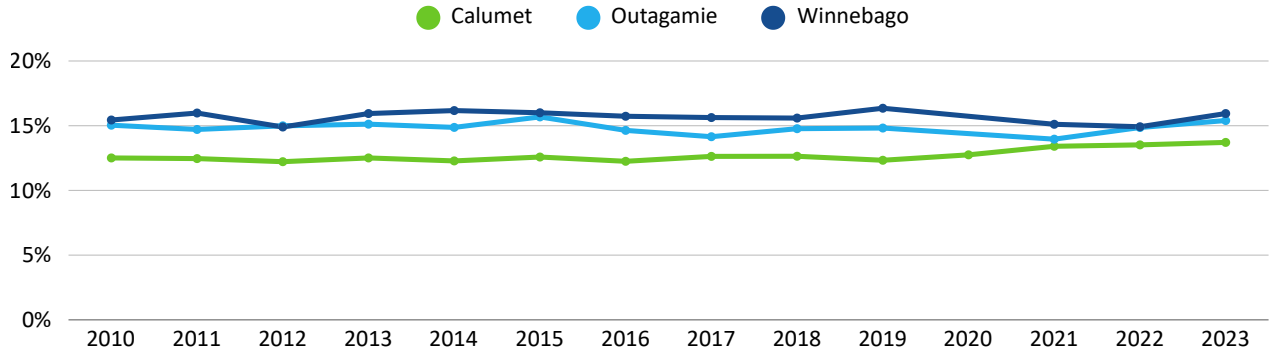


For American families, homes remain their greatest source of wealth (Marohn and Herriges, 65). In the Tri-County area, home ownership doesn't look the same for all groups. 73% of white households own their home, meaning they benefit as their home's value increases. But only **27% of Black** households and **44% of Hispanic/Latino** households own their home. This means these groups are less likely to benefit from rising home values. This isn't unique to this region. After all, "virtually all of the increase in wealth inequality in the United States in the past four decades is accounted for by the increase in the share of capital in housing" (Marohn and Herriges, 100).

Humane Housing



Rent in the Tri-County region has mostly remained **stable** for the past 15 years, relative to incomes.



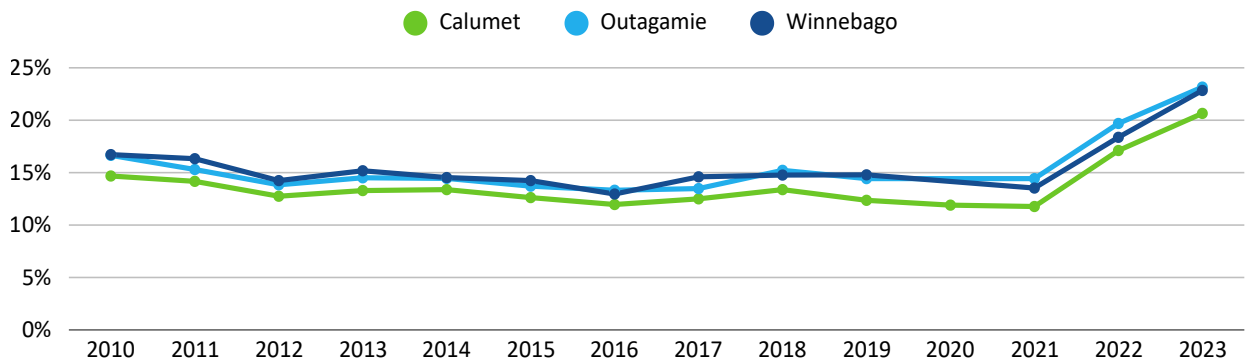
(ACS Tables S1903 and B25064: Median Annual Gross Rent as Percent of Median Annual Income)

*1-year ACS estimates used for Outagamie/Winnebago Counties to avoid smoothing and better capture recent volatility.



Rent has been affordable for median earners who already have a place to live. However, inflation has made rent harder to afford for minimum wage earners since 2009, when the minimum wage was last raised. It has also become harder to find an apartment due to the low supply. This is especially true for families with children, who struggle to find rental units with adequate space.

Homebuyers have to **pay more** of their income on mortgage costs since 2020.



(ACS Tables B25077 and S1903, Bankrates: Median Annual Mortgage (10% Down, US Avg. Ann. 30-Yr. Fixed Mort. Rate) as Percent of Median Household Income)

*1-year ACS estimates used for Outagamie/Winnebago Counties to avoid smoothing and better capture recent volatility.

Homebuyers in the Tri-County area now have to commit more than 20% of their income to mortgage payments alone. This doesn't include property taxes, home insurance, private mortgage insurance, or utilities. Getting closer to 30% means homeowners are more likely to face housing cost burden. **Homeownership is getting harder across the Tri-County region.**



Humane Housing



How Did We Get Here?

Homeownership is one of the most important ways families build intergenerational wealth. Many parents pass homes down to their children to provide stability and financial security. This practice has not been equally available to everyone in the Tri-County region. During Reconstruction, Black residents owned homes and businesses in the Fox Cities. But by 1930, cities like Appleton had become “sundown towns.” These are cities where Black people could neither live nor stay overnight (Vasquez). Authorities used anti-vagrancy laws to make Black people leave the city after work. And places like Oshkosh had a visible Ku Klux Klan presence. Fear of racism and violence drove most Black residents to leave the community (Vasquez). In the 1940s and 1950s, some housing developments added racial covenants. These contracts legally prevented Black people from buying homes (Unvarnished).

It wasn't until the 1960s that Black residents began moving back to the Tri-County area. In 1968, the National Fair Housing Act was passed to prevent discrimination (Fair Housing Act). Still, many Black residents struggled to purchase homes because of racist lending practices. Today, local community leaders promote equal access to homeownership. But it's important to understand why inequality persists. We saw on an earlier page that a majority of Black households don't own their home. Historically, local white families have been able to benefit from homeownership. In contrast, many Black families have been denied this opportunity. They have not been able to build intergenerational wealth via housing. This disparity is systemic and cannot be quickly fixed. It requires intentional, sustained efforts to undo.

New Problem: Housing Supply Shortage

There are not enough homes for sale, and prices have been rising quickly. Private equity and investors make it even harder for real people to buy homes. Investors can afford to pay more for houses, meaning real people have to raise their offer or be outbid. We see investors turning houses in the Tri-County area into short-term rentals like AirBnBs. Or they build a portfolio of long-term rentals, which might be managed by faraway landlords. This funnels wealth outside our community and takes away housing supply from the people who truly need it. In early 2022, the highest offer on one in five homes in America was an investor (Marohn and Herriges, 67). As investors buy more local properties, families may have to either rent or leave the area. But rentals that can accommodate families are also in short supply.

Single-family zoning makes the problem worse. This type of zoning only allows the construction of single-family homes with yards and driveways in large parts of our community. Elder homeowners often have no smaller housing options in their neighborhood. They have to choose between aging in place or losing the relationships they've built with their neighbors. Many choose to age in place, which means fewer houses are on the market and home prices go up. And single adults, low-income families, and first-time homebuyers may not want a single-family home with a large yard. But that is the majority of what zoning ordinances allow. Single-family zoning also creates car-dependent neighborhoods that people have to leave in order to live their lives. This is unhealthy for physical, mental, social, and financial health.

Where Do We Go Next?

First, we need to treat housing more as a basic need and less as an investment. Shelters like Pillars and Day by Day should be last-resort options. It's important to build ample housing supply in walkable neighborhoods that meet residents' basic needs. We can also question policies that permit short-term rentals to buy up housing supply. And we can acknowledge that inequalities exist and work to combat them.

Basic Needs for Health and Safety



Basic Needs are essential to navigating day-to-day life. The category is large and overlaps with other categories like housing. We need to fulfill our basic needs before we can focus on anything else. Explore the data below to find out where our communities are succeeding and where there is room for improvement.



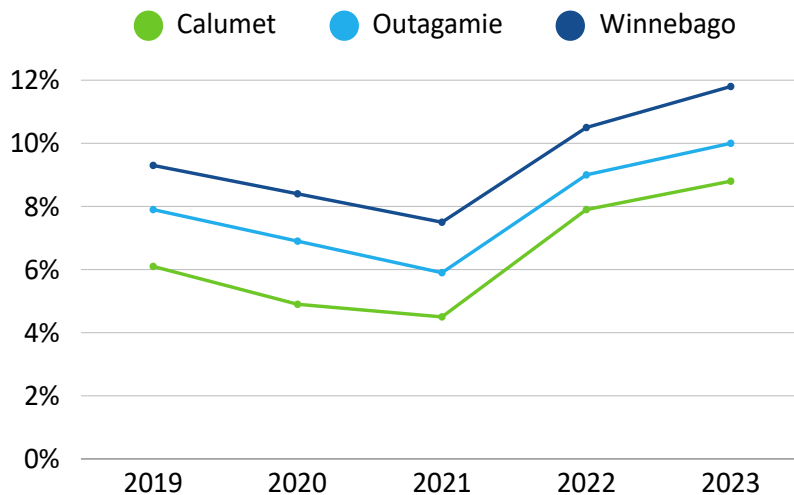
Every time something gets better at work, I lose help for food.



Basic needs are getting more expensive as benefits are going away.

- Food insecurity (limited or uncertain access to adequate food) is going up.
 - The cost of food has risen faster than inflation.
 - SNAP (Supplemental Nutrition Assistance Program) benefits cover less than they used to.
- Many in our community do not have access to the healthcare they need.
 - Federal program cuts and rising premiums are hurting the lowest earners.
 - Behavioral healthcare is particularly difficult to access.

Food insecurity has been trending up since 2021.



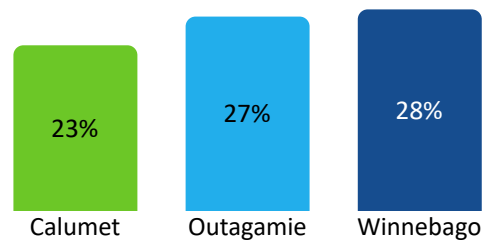
(Feeding America Map the Meal Gap)

- About 10% of the Tri-County population meets Feeding America’s definition of “food insecure,” using USDA data.
- Most people living in poverty are food secure because they have benefits to help them afford food.
- People earning above the poverty line may lose benefits, causing food insecurity.

Food is getting more expensive.

- Food prices rose 11% faster than general inflation from Dec. 2020 to Dec. 2024 (Davidenko and Sweitzer).
- Rising food costs hurt poor families more because they have less discretionary spending to cut.
- SNAP benefits, commonly known as “food stamps,” are not enough to cover food costs for modest meals (Urban Institute Data Tool).

A modest meal in the Tri-County costs about **25% above** what **SNAP benefits** cover.



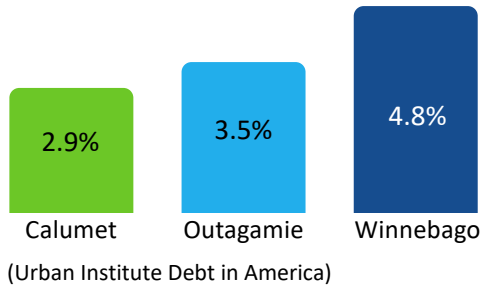
(Urban Institute Data Tool)

Basic Needs for Health and Safety



Access to care means being able to get medical, dental, and mental health care when it is needed, without too many barriers like cost, distance, or long wait times. It includes having enough providers nearby, affordable services, and insurance or programs that help cover costs.

About 4% of the Tri-County population - or roughly 17,000 residents - **are uninsured.**



- Non-white residents are more than 3 times as likely as white residents to be uninsured.
- Uninsured Americans are less likely to seek preventative care and often delay necessary medical care.
- Uninsured Americans are more susceptible to emergency medical expenses and debt.

Wisconsin Medicaid

Approximately 1 in 5 Wisconsinites (or 1 million people) receive health care coverage and services through Wisconsin's Medicaid programs. Almost half of Wisconsin Medicaid members are kids. Anyone with a ForwardHealth card has Wisconsin Medicaid, including members of:

- BadgerCare Plus
- Children's Long-Term Support Program
- Family Care Partnership
- Family Planning Only Services
- Family Care
- IRIS
- PACE

Our community members risk losing health insurance coverage.

Many people may lose their health insurance as a result of federal budget changes from the Big Beautiful Bill. The federal budget cuts Medicaid by about \$1 trillion over the next 10 years and other spending that helps people afford health insurance. By cutting Medicaid and Affordable Care Act coverage:

- **276,000 people in WI will lose health insurance.**
 - The Medicaid work requirement will cause an estimated **63,000 in WI to lose BadgerCare.**
 - The expiration of the premium tax credit will cause an estimated **30,000 in WI to lose health insurance** (WI DHS).



Even those of us with two incomes and full-time employment struggle to access needed healthcare due to costs, high deductibles, lack of available providers covered in insurance plans, and an inability to leave work to access needed medical appointments.

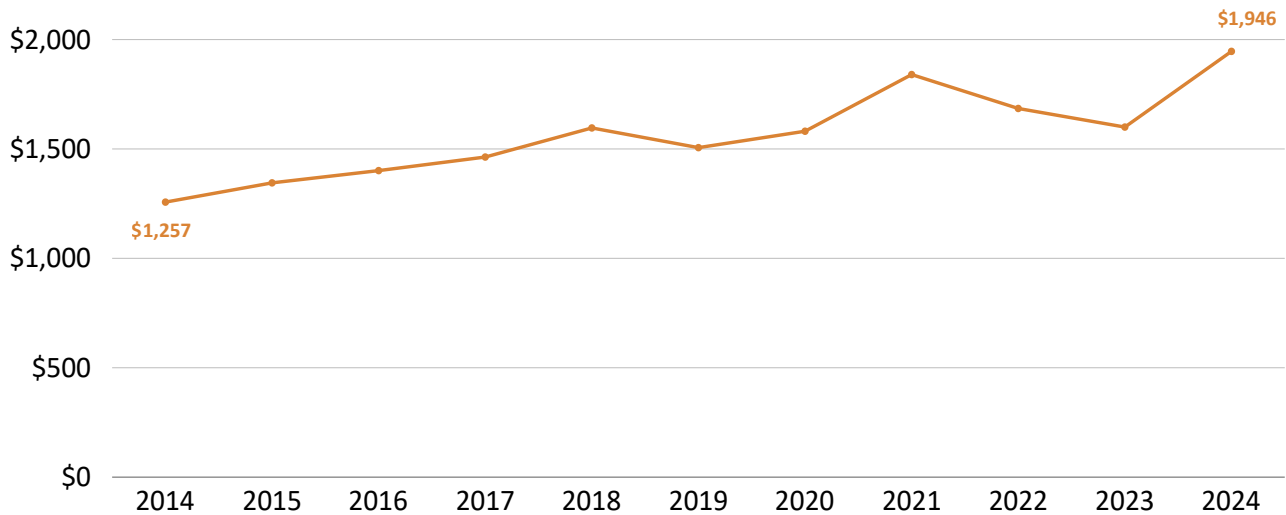


Basic Needs for Health and Safety



Employer-based health insurance is the most common type of coverage for Tri-County residents. Employees and their employers both contribute to “premiums,” the fixed cost required to maintain insurance coverage. In this model, coverage is tied to an employee’s employment status. Employers often negotiate cheaper plans than individuals could buy on their own in the marketplace. However, this can lead to “job lock,” where employees are unable to freely leave their position because the loss of benefits will be detrimental to their finances and/or health.

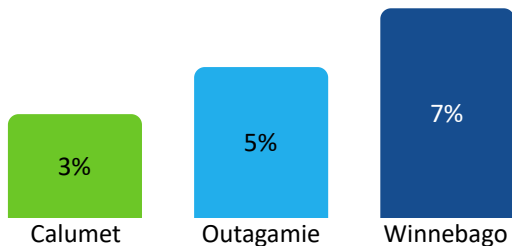
Average annual **employee premiums** for employer-based health insurance in Wisconsin have **increased by 55%** over the past decade.



(Kaiser Family Foundation)

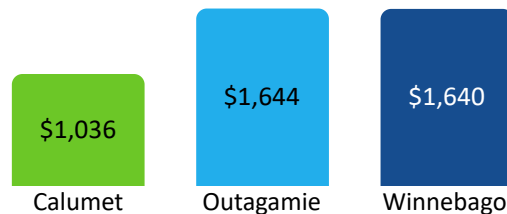
The increase in employee premium contributions **exceeded general inflation**, which rose by only about 32% over the same time period (Bureau of Labor Statistics). This means that health insurance has become more expensive for employed Wisconsinites. However, because of job lock, employees may have no other viable alternatives. For residents who earn less money, and therefore have less discretionary spending to cut, this causes acute financial pain and may result in choosing between health care and other necessities.

More than 5% of the Tri-County population has medical debt in collections.



(Urban Institute Debt in America)

For residents with **medical debt** in collections, the **median debt is well over \$1,000.**



(Urban Institute Debt in America)

Basic Needs for Health and Safety



Demand for behavioral health (mental health and substance use) services has increased in the past three years, but availability isn't keeping up. It's important to encourage help-seeking behavior, which assists in breaking down years of cultural stigma against mental health care. However, if help-seeking behavior is met with waitlists or rejections from providers, people can experience further mental harm.

A lack of mental health care is causing spillover.

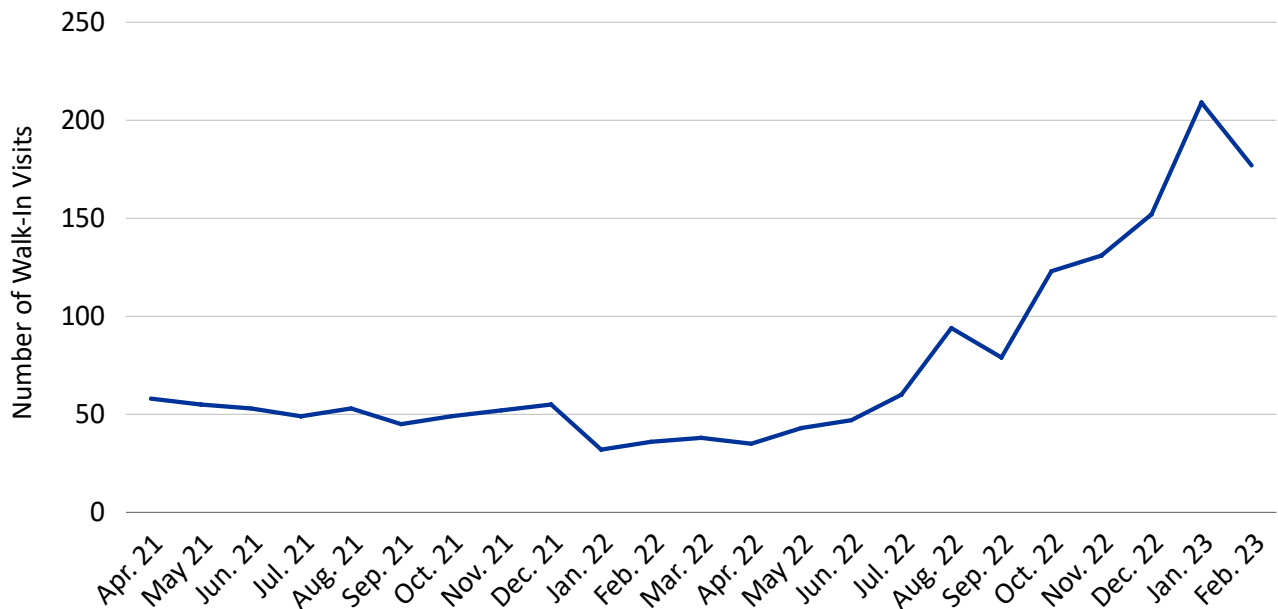
- Mental health-related calls are the second most common type of call to 211 in the Tri-County since January 2022 (211 Counts).
- Mental health provider waitlists have increased across the Tri-County since the COVID-19 pandemic.
- Patients sometimes do not feel their cultural needs are met by their mental health care provider, and choose to find a new one or seek help elsewhere.
- Law enforcement agencies, schools, emergency departments, and other entities report having to handle mental health needs for which they are not the best fit.



The COVID pandemic really accelerated the mental health care crisis. So many more people needed behavioral health treatment all at once. As a provider, I think it's great we collectively challenged so much of the stigma surrounding mental health help. But the system doesn't have an adequate number of providers to handle the flood. Especially in 2022, I watched waitlist lengths soar in the Fox Valley, and we still are just doing our best to triage. We need more providers, and more diverse providers. The system needs help.



Utilization of one local behavioral health walk-in clinic increased substantially beginning in late 2022.



(Mind Your Wellness Survey, 2023)

Basic Needs for Health and Safety



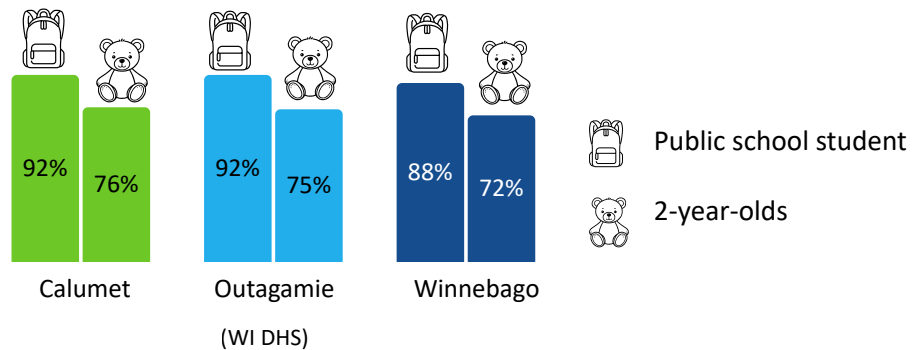
Preventative health care focuses on maintaining good health and preventing diseases before they occur. Prevention is fiscally responsible by preventing diseases before they become severe. Early detection means fewer hospital visits, less expensive treatments, and lower financial burden on individuals and healthcare systems.

Childhood Vaccines

Vaccinating infants is critical because their immune systems are still developing and vulnerable to serious or even fatal vaccine-preventable diseases (CDC).

All three counties have seen a decline in vaccinations that are recommended to be completed by age two. However, most school-age kids are fully immunized, which may be due to parents waiting and/or spacing out infant vaccinations and to Wisconsin school immunization law requirements.

Public school students who met immunization requirements (2023) compared to 2-year-olds fully immunized (2022)



Oral Health and Dental Care

Good oral health reduces cancer risks, improves diabetes control, lowers opioid use, decreases school absences, boosts productivity, and extends life. Untreated oral disease costs the US over \$45 billion annually in lost productivity (CDC).

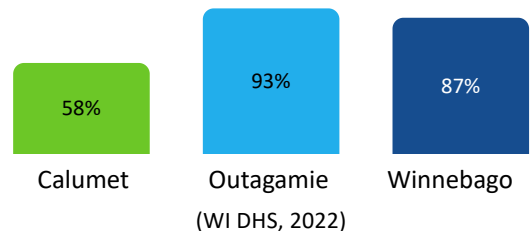
1 out of 3 adults in the Tri-County region did NOT visit the dentist in the past year for routine care (CDC Places, 2022).

Fluoridated Water

Providing optimally fluoridated water to US communities for 1 year **saves \$6.5 billion in dental treatment costs and offers an average return on investment of \$20 for every \$1 spent.**

On average, communities with water fluoridation experience 25% fewer cavities, saving \$32 per person annually by avoiding dental treatment costs and leading to fewer missed work and school days (CDC).

Percent of population on public drinking water who had access to fluoridated water



Basic Needs for Health and Safety



How Did We Get Here?

The 2010 Affordable Care Act (ACA) greatly reduced uninsured rates in Wisconsin. In 2013, before the ACA took effect, more than 9% of Wisconsinites lacked health insurance (Friedsam). By 2016, only 5.4% of residents were uninsured. The ACA prevents insurers from denying coverage due to pre-existing conditions, provides cost assistance to make insurance more affordable, and allows young adults to stay on their parents' insurance until age 26. According to Governor Tony Evers, 313,579 Wisconsinites bought health insurance through the Affordable Care Act in the most recent enrollment period, the most ever for our state. 88% of those enrollees qualified for premium tax credits that made insurance more affordable.

In the 2010s, then-Governor Scott Walker sought to expand drug testing to FoodShare recipients with no history of drug use. His December 2017 press release stated he “approved a plan to implement drug screenings for able-bodied adults participating in the FoodShare Employment and Training (FSET) program” (Walker). Proponents argued the plan would provide drug treatment services to Wisconsinites in need. However, many FoodShare applicants felt they were being stigmatized as likely drug users due to their low income. Substance use treatment options are important, but linking them to FoodShare implies that benefits recipients make bad choices and “don’t deserve assistance.”

New Problem: Cuts to Existing Programs

Congress has ended the Supplemental Nutrition Assistance Program Nutrition Education and Obesity Prevention Grant Program (SNAP-Ed), effective October 1, 2025 (Ward). SNAP-Ed, known as FoodWise in Wisconsin, provided education about making healthy meals on a budget and preparing various ingredients. The program also provided education about incorporating physical activity into daily life. Wisconsin DHS estimates that, for each dollar spent on FoodWise funding, “\$10 was saved in long-term health care costs” (“Nutrition”). These cuts will impact predominantly low-income residents in the Tri-County area.

At the time of writing, the federal government has been shut down for approximately one month. It would be inappropriate to speculate on its resolution. However, each government shutdown threatens funding for programs like SNAP, which forces local food pantries and Feeding America Eastern Wisconsin to prepare for food shortages for vulnerable community members. This causes undue burden on our local systems. Additionally, ACA premium tax credits are set to expire in 2026, and it is unknown whether Congress will extend the tax credits in the coming weeks. The average ACA tax credit in Wisconsin is more than \$7,900 per year. Because of uncertainty, many Wisconsinites have had to plan for large increases in their insurance premiums, preparing to choose between much higher costs or going without health insurance at all.

Where Do We Go Next?

National-level influences can feel overwhelming. But local organizations like shelters, food pantries, community closets, and free/low-cost clinics work to address basic needs gaps every day. Organizations like Feeding America Eastern Wisconsin and Vivent are experts in this space. We can educate ourselves about national threats to basic needs and how they will impact us locally. We can identify the organizations best positioned to meet the moment. We can promote fundraisers, volunteering, and resource drives to support those organizations. And we can ask vulnerable community members what they need.

Lifelong Learning

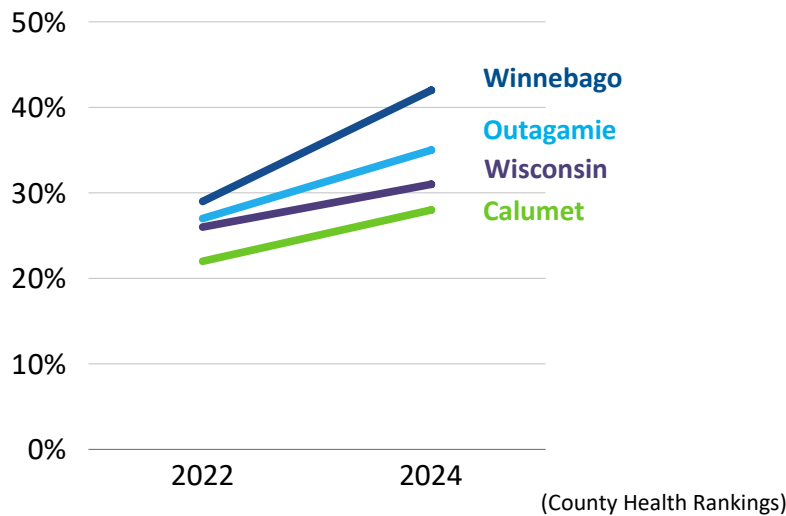


Lifelong learning is about providing a good education for all that ensures everyone, regardless of age, background, or ability, is set up for success, and has opportunities to reach their full potential. Education can launch people into meaningful careers with ongoing opportunities to learn and grow.

Healthy childhood development is a key indicator of future health outcomes.

- Healthy children are more likely to be academically engaged, have higher employment and earnings, and use costly systems less frequently.
- High-quality child care and preschool programs can improve children’s health outcomes throughout their lives and generate long-term savings for individuals and society (Guevara).
- Poverty creates significant educational barriers.
- 58% of Wisconsin’s high-paying future jobs through 2030 will require a bachelor’s or advanced degree (Wisconsin Policy Forum).

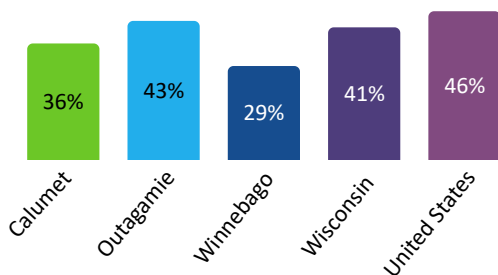
The percent of household income needed to pay for child care for 2 kids is rising.



“
I can’t afford childcare without two incomes. My husband makes just enough that we don’t qualify for assistance.
 ”

Child care and Pre-K are strategic economic investments.

Preschool enrollment for 3-4 year olds



(ACS Table B14003, 2023 5-year est.)

Decades worth of studies - one strong message:

Kids who attend public preschool programs are better prepared for kindergarten than kids who don’t.

- While all kids benefit, poor and disadvantaged kids make the most gains.
- Preschool programs with a well-implemented evidence-based curriculum have the best results (NPR).

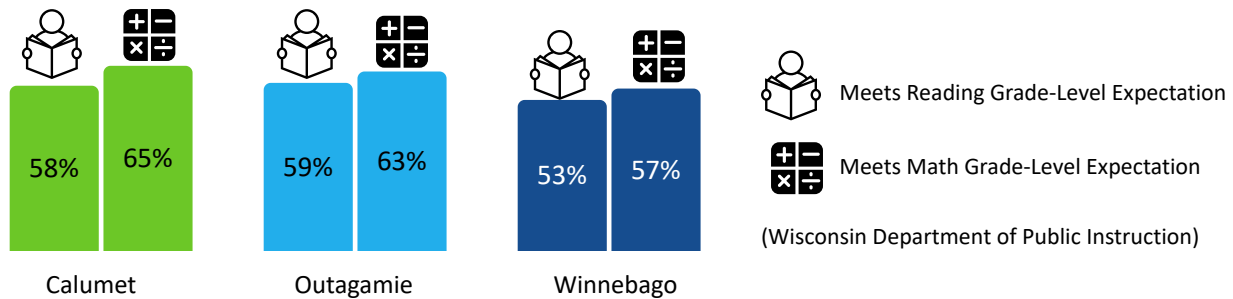
Lifelong Learning



Elementary school is where children learn to read, write, and grasp core concepts in math and science, which are essential for all subsequent learning.

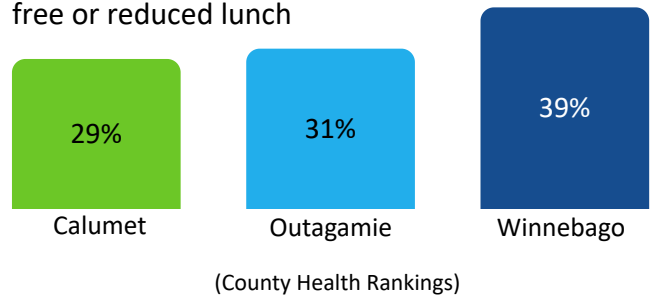
Middle school is a transition period, important for building foundational skills and critical thinking for continued success.

Percent of **students in grades 3-8** who met **grade-level** expectations in **reading and math** for the 2023-24 school year



Poverty creates significant educational barriers by causing stress, affecting health and nutrition, limiting access to essential resources like books and technology, and creating unstable home environments that hinder learning.

Percent of children in public schools **eligible** for free or reduced lunch



Black and Hispanic/Latino and Asian children are often disproportionately living in poverty.

	Calumet	Outagamie	Winnebago
Black	29%	20%	57%
Hispanic/Latino	19%	27%	29%
Asian	21%	9%	24%
Native American	N/A	15%	1%
White	4%	4%	8%
All	5%	6%	11%

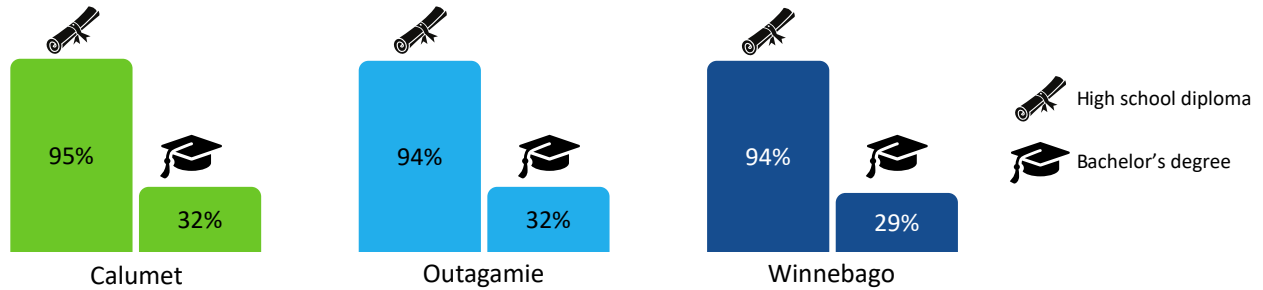
(County Health Rankings)

Lifelong Learning



In the Tri-County area, about 95% of people 25 and older have a high school diploma, compared to about 30% who hold a Bachelor's degree.

Education level of the population 25 and older



(ACS Table B15002, 2022 5-year est.)

Student Loan Debt in Wisconsin

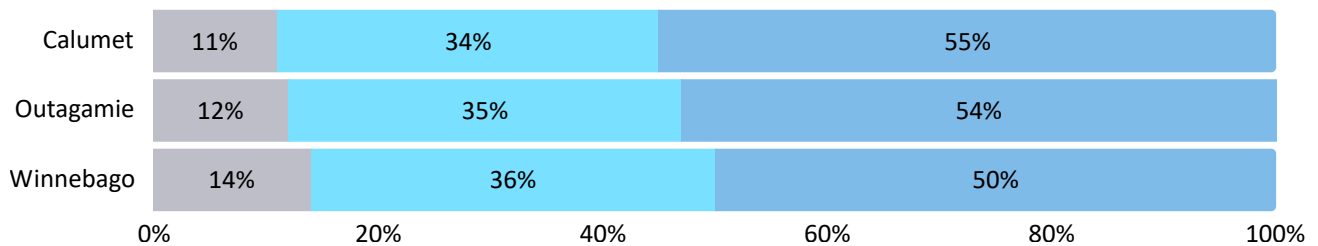
Obtaining post-secondary education can come at a high cost.

- 12.1% of state residents have student loan debt (or 723,500 people).
- 54.4% of them are under the age of 35.
- \$32,619 is the average student loan debt.
- Total student loan debt for WI residents is \$23.6 billion (Education Data Initiative).

Adult Literacy

“Literacy is understanding, evaluating, using, and engaging with written text to participate in society, to achieve one’s goals, and to develop one’s knowledge and potential” (National Center for Education Statistics).

Estimated percentages of adults (age 16-74) with literacy scores of 1, 2, or 3



(National Center for Education Statistics)

- Level 1 (Poor Skills): Basic sight vocabulary and can read short texts on familiar topics to locate a single piece of information.
- Level 2 (Weak Skills): Can read paragraph-length texts, compare information from the text with what is already known, and draw straightforward inferences.
- Level 3 (Suitable Minimum): Sufficient for managing the requirements of daily life and work in a complex society.

Lifelong Learning



Child Care Crisis: How Did We Get Here?

The early care and education industry is labor-intensive and requires a high level of staffing to ensure children are in a safe, healthy, and developmentally appropriate environment.

Add in higher insurance costs due to increased liability, plus rent, food, supplies, utilities, and more, and a provider's financial resources are stretched thin.

These thin margins prevent child care providers from paying employees competitive wages, resulting in high turnover and staffing shortages that leave classrooms empty. Why not just raise rates? Because families are already struggling to pay the current prices. By raising rates, providers risk having families leave their program because they simply can't afford it, leaving families without the child care they need in order to participate in the workforce and providers without the revenue they need to keep their doors open.

Three Critical Areas:

Access

Many child care providers have unfilled capacity, meaning they're not serving as many children as they're licensed to serve. Statewide, providers report that they are under capacity by 33,000 children. At the same time, half of the providers report having a waitlist. With a lack of staff, child care providers are stuck closing more classrooms and serving fewer children while watching their waitlist continue to grow. This is causing parents, especially women, to leave or not enter the workforce, costing Wisconsin at least \$1.1 billion per year in lost economic productivity, earnings, and revenue.

Workforce

Gaps in access to child care stem directly from staffing shortages. Due to razor-thin margins, Wisconsin child care centers only pay lead teachers an average of \$13.55 per hour. That's 69% less than the average hourly wage of \$28.34 for Wisconsin workers. On top of that, at least half of the child care programs in Wisconsin lack employee health insurance benefits. Unlivable wages combined with a lack of benefits are causing qualified early care and education professionals to leave the field. It's no surprise that half of child care center directors report that keeping staff or filling staff vacancies is "very" or "extremely" challenging. This workforce shortage is the main reason that providers are reducing their capacity and have waitlists. Over half of center directors report that staffing challenges are causing them to serve fewer children and turn families away.

Affordability

The average price of center-based care for one infant is more than \$11,900 per year. That's 16% of the median household income in Wisconsin and equivalent to an academic year at UW-Madison. Unlike college, child care is paid in cash, up-front, at a time when families are just starting. Yet, that price doesn't come close to \$33,715 – the average true cost of care for an infant, and what providers would need to pay their staff fairly and cover all expenses of running their business. And when we are planning for our children's futures, we need to view local resources like Fox Valley Technical College, UW-Oshkosh, and UW-Extension as the important and affordable community assets that they are.

Reliable Transportation



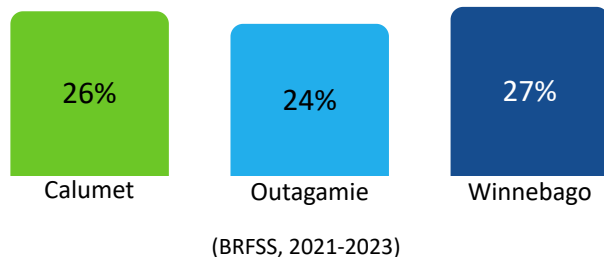
Transportation is about reaching the spaces where we live our lives. It's how we access resources, workplaces, and peers. Explore the data below to find out where our communities are succeeding and where there is room for improvement.

“
If I don't have a car at home, I feel trapped. I wish it were easier to get around by bike or on foot, but I just don't feel safe.
”

Our community feels stuck with only one choice: Driving.

- Active transit is better for our health.
 - Physical activity prevents chronic conditions.
 - Bicycling and walking encourage connection with our community.
 - Time spent outside exercising improves mental health.
- Driving is expensive and has inherent risks.
 - The average Wisconsin driver will spend over \$3,500 per year on gas and car insurance alone.
 - There's one car crash each year for every fifty people in our area.
- We don't have an adequate public transit system.
 - Disinvestment in public transit has made it inconvenient or unusable for many residents' daily lives.
 - Less than one percent of residents regularly use public transit.

More than a quarter of Tri-County residents report **zero exercise** outside of work in the **past 30 days**.



Active transit is a large portion of people's physical activity in many parts of the world. In the Tri-County area, fewer than 3% of all residents walk or bike as a form of transportation (ACS Table S0801, 2023 5-year est.).

In the Tri-County area, more than one-quarter of residents do not participate in any physical activity outside of work. Not even walking. According to the CDC in 2023, more than one-third of all Tri-County residents are considered "inactive" or "insufficiently active" (BRFSS, 2023).

The US Department of Transportation states investment in bicycle and pedestrian spaces "creates opportunities for people to exercise" and "reduces the risk of associated conditions such as diabetes, cardiovascular disease, and premature death."

Tri-County residents average 40-45 minutes per day driving to and from work. That's a lot of sedentary time.

The average employed Tri-County resident takes **more than 20 minutes to drive to work**.



Reliable Transportation

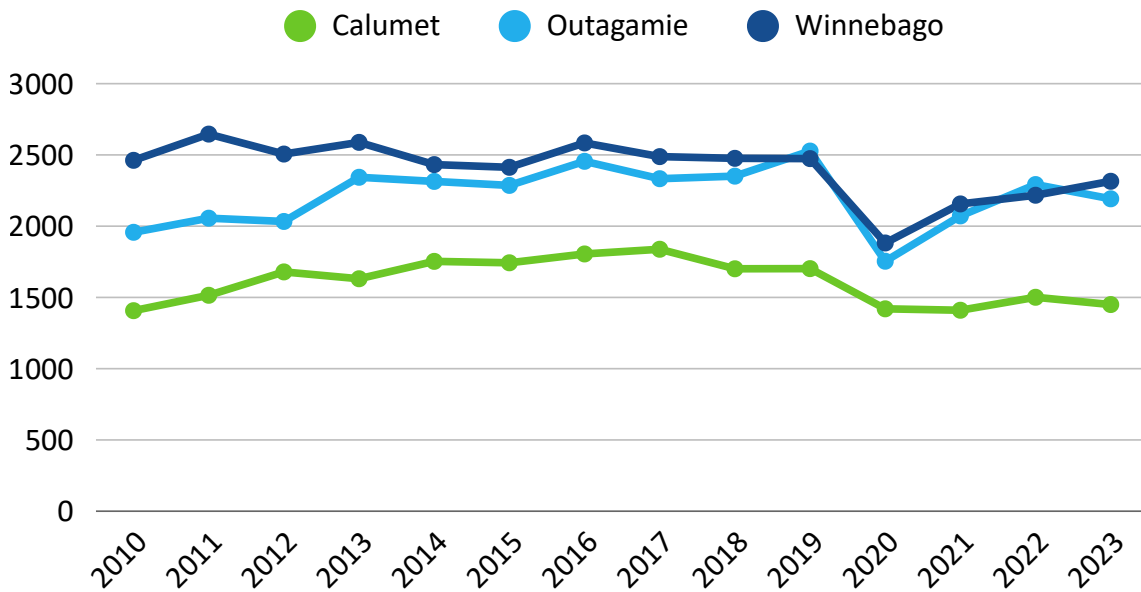


Not only is **active transit** good for our physical health, but it also **provides mental health benefits**. A 2023 comprehensive literature review showed there is an abundance of research suggesting active transit, or “walking and cycling to get to and from places, provides significant benefits in terms of mental health” (Scrivano et al., 19). Being outside and moving helps connect us to our community. It facilitates person-to-person interactions. And it has the potential to reduce stress if it’s in a safe and comfortable space.

Community residents report that **active transit is not always possible here**. One resident notes, “Just because you have a bike lane doesn’t mean it goes anywhere. Sometimes they dump you out right into heavy traffic. There needs to be more thought about where they go.”

Physical barriers between bikes/pedestrians and cars are the gold standard. Bike lanes can be great. But ask yourself this: Would you be comfortable letting your child bike in a bike lane knowing that only a strip of paint separates them from 35 mph traffic? If it’s not safe enough for a child to use, it might not be the best infrastructure.

Annual Count of Car Crashes by County



(WisDOT Community Maps)

Car crashes are common in the Tri-County area. Annually, there is more than 1 car crash for every 50 residents in the Tri-County area. These crashes can sometimes lead to severe injury or death. In every year since 2010, at least five of our neighbors have been killed in car crashes. Crashes are especially dangerous to bicyclists or pedestrians. We have had pedestrians killed by car crashes as recently as September 2025. And deaths of pedestrians hit by cars increased by 48% nationally between 2014 and 2024 (Governors Highway Safety Association).

Reliable Transportation



Car use is almost universal in our community.

- 98% of homeowners have a vehicle.
- 90% of renters have a vehicle.
- Less than one percent of residents use public transportation.

(ACS Tables B25044 & S0801, 2023 5-year est.)

“

This is a must-have car place.

”

Car ownership is expensive.

Expense	Average Annual Cost in WI
Gas	\$1,992
Car Insurance	\$1,664
Licensing Fee	\$85
Repair Costs	\$361
Loan Payments	\$7,068
Total	\$11,170

The average car owner in Wisconsin pays more than \$11,000 annually to drive.

In contrast, the annual cost to a Valley Transit rider in the Fox Cities is \$720. The annual cost to an Oshkosh GO Transit rider is \$480.

On average, it is more than 90% cheaper to ride local public transit than it is to drive.

Still, less than 1% of residents use public transit regularly for transportation.

(Rosenfeld; Horymski)

To overcome **barriers to transit use**, residents report wanting:

“

Our elderly population is growing and many will lose the ability to drive so buses are essential for people to continue to enjoy their lives.

”

- More stops to accommodate a wider geographic area and destinations
- Increased frequency - hourly service is not frequent enough for many residents
- More shelters for riders waiting for the bus
- Service on Sundays

(“Valley Transit: Ridership and Fare Payment Surveys”)



Reliable Transportation



Public Transportation

Valley Transit partners with 9 municipalities, 3 counties, and many other entities to provide diverse transportation services across the Fox Cities area. There are 18 routes. In addition, the VT Connector is a fully accessible shared-ride van service designed to supplement Valley Transit’s bus service. In the past few years, Valley Transit has struggled to fill bus driver positions, resulting in a decrease in bus service times and routes.

Greater Oshkosh Transit (GO Transit) offers fixed-route bus service and Americans with Disabilities Act (ADA) complementary paratransit, GO Plus. Fixed-route service is operated directly by the City, while Oshkosh City Cab Company and Cabulance operate GO Plus service through a contract with the City. Additional paratransit services include Senior Dial-A-Ride and Access to Jobs (ATJ). GO Connect is a new Microtransit service linking Oshkosh and Neenah, operated by Oshkosh City Cab and Cabulance.

In Calumet County, public transportation options are limited and are available to those 60 years old and up or people with disabilities. These services are provided through Make the Ride Happen, offered by Lutheran Social Services. The county also provides transportation services to this group of people.

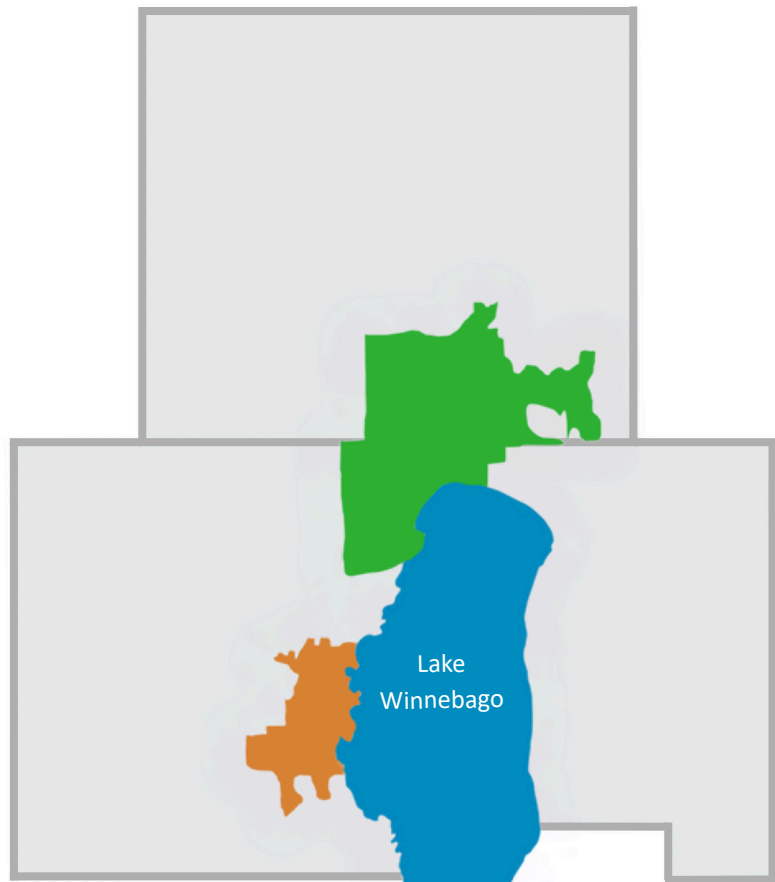
Tri-County Fixed-Route Public Transit Service Map



Valley Transit: Fixed-Route Service Area (Hourly Service)
M-F 5:45 AM – 6:30 PM
Sat. 7:45 AM – 1:30 PM
Sun. No Service



GO Transit: Fixed-Route Service Area
(Service Every Half Hour)
M-Sat. 6:15 AM – 6:45 PM
Sun. No Service



Reliable Transportation



How Did We Get Here?

Over the past several decades, transportation infrastructure in our region has evolved in ways that heavily prioritize car travel, often at the expense of active and public transit options.

This trend can trace some of its origins to the Interstate Highway Act of 1956, which encouraged suburban sprawl and the development of car-centric communities. As a result, riding a bike or walking is still stigmatized as a mode of transportation. By 1969, the highway that would eventually become I-41 attained freeway status by eliminating all crossroads. This is especially problematic in areas such as Grand Chute, where the absence of sidewalks under I-41 makes travel unsafe and strenuous for residents without cars who are trying to cross the freeway.

Public transit has also been heavily stigmatized in America. The Tri-County region is not immune to this stigmatization, even though there are dedicated public servants working to provide transportation options to our residents. Transit networks have not had the resources to develop much outside of areas with the highest population density, as is the case in much of the country.

Decline of and Opposition to Alternative Transit Options

Recent developments have further strained transportation access. In September 2025, the Amtrak Thruway I-41 Bus Service between Green Bay and Milwaukee was discontinued, reducing regional connectivity (Wisconsin Department of Transportation). Additionally, since July 2024, Valley Transit bus services have faced cutbacks, ending at 6:00 PM on weekdays and 1:00 PM on Saturdays. According to Ronald McDonald, General Manager of Valley Transit, the biggest problem is a lack of CDL-licensed drivers willing to do the job (Cornelius). Residents in the Valley Transit service area can still use the Valley Transit Connector, a shared-ride service that expands transit outside the scheduled fixed-route bus service. In the Oshkosh area, Oshkosh GO Transit Transportation Director Jim Collins says service cuts are also under consideration (Moore). This could mean hour reductions or even the elimination of Saturday bus services.

Meanwhile, attempts to improve infrastructure for non-car travel, such as the High Cliff Connection project connecting downtown Menasha with High Cliff State Park, have faced resistance to bike lanes and sidewalks in residential areas. This can mean long workarounds that make travel more difficult for pedestrians and bicyclists.

Where Do We Go Next?

Despite these challenges, there are promising opportunities ahead. One major proposal is the exploration of a rail line between Green Bay and Milwaukee, which could reestablish crucial regional connectivity. On a local level, communities have used traffic-calming measures like removing traffic lanes to make room for bicyclists and pedestrians. On streets such as College Avenue in Appleton or Lake Park Road in Menasha, this has created more balanced and accessible streets for all users. Investing in active transit infrastructure, such as protected bike lanes and continuous sidewalks, can also improve safety and accessibility. Promoting CDL training programs and highlighting the benefits of employment at our public transit authorities may help address the ongoing driver shortage.

Thriving Natural World



Access to clean air, safe water, healthy land, and resilient ecosystems is essential for good health. Sometimes, the air we breathe, the water we drink, the food we eat, and the homes, buildings, and neighborhoods we live and work in disrupt how our bodies work, causing us to become sick.

Environmental factors can either prevent disease and promote mental health and physical well-being, or contribute to their decline.

- Residents and visitors to the Tri-County region value the parks, trails, green space, and time spent in nature.
- Good water quality is essential as a source of drinking water, supporting agriculture and tourism, and for healthy recreational opportunities.
- Poor air quality can cause respiratory problems, cancer, and mental health issues like anxiety and depression.
- Lead is a naturally occurring metal and is toxic to humans when swallowed or inhaled.
- A changing climate is bringing warmer winters, wetter springs, and more extreme weather events that can lead to serious health issues.

“
The parks are great... [it's] open and enjoyable being on the Fox River or Winnebago. It's very scenic.

Parks & Outdoor Spaces

The Tri-County region is full of outdoor recreation and tourism opportunities, including:

- An abundance of city and county parks
- High Cliff State Park and several multi-use trails
- Nature centers and preserves
- Community pools
- A network of lakes and rivers that encompasses the Fox-Wolf River Basin and the Lake Winnebago System



Our region provides ample opportunities for hiking, biking, bird-watching, playing on playgrounds, boating, fishing, kayaking, skiing, snow-shoeing, and more. Our Planning departments and Parks and Recreation departments, along with the East Central Wisconsin Regional Planning Commission, ensure that parks and trails are maintained and accessible.

Unique attractions to enjoy the outdoors in the Tri-County Area include:

- Children's Farm at Plamann Park
- Menominee Park Zoo
- Courts & playing fields (volleyball, pickleball, soccer)
- Children's playgrounds
- Disc golf courses
- Cave tours
- Fishing piers
- Marinas

Health Benefits of Green Spaces

Improved mood & mental health

Stress relief

Improved brain function

Increased social connectedness

Improved creativity & mindfulness

(Wolf)

Thriving Natural World



Water Quality

Water quality is important for human health, environmental stability, and economic well-being.

Maintaining good water quality prevents illness by minimizing contaminants, supports wildlife and plant life, and underpins industries like agriculture and tourism. Preserving good water quality is an investment in future generations.

Drinking Water

Drinking water quality and safety depend on its source. Sources are either surface water (rivers, lakes, reservoirs) or groundwater (aquifers reached by wells). More than 200,000 people get their drinking water from Lake Winnebago (Fox-Wolf Watershed Alliance).

Most tap water is delivered by utilities through public water systems, where it is treated and purified. Private well systems, more common in rural areas, are another way to get drinking water. Wells are not regulated like public systems. Well owners can ensure the safety of their drinking water by conducting regular maintenance and testing annually for bacteria, arsenic, and nitrates.

Drinking Water Threats: Arsenic (As)

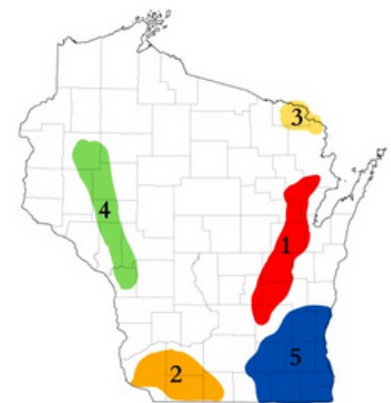
Arsenic can naturally occur in soil and rock formations, but can also come from some types of pesticides, treated wood, and certain foods. Outagamie and Winnebago Counties have naturally occurring arsenic in the groundwater.

Drinking water with high levels of arsenic can cause skin rashes and stomach problems. Arsenic can also increase the risk for certain kinds of cancer. Infants and children are especially sensitive to arsenic, and high levels can affect cognitive development (WI DHS).

Drinking Water Threats: Nitrates (NO₃⁻)

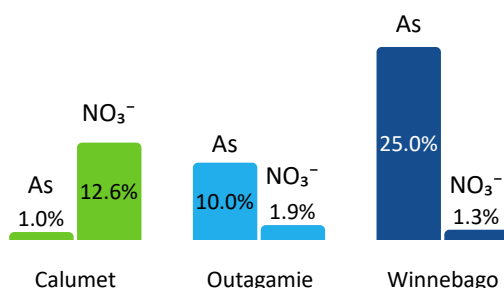
Nitrate naturally occurs in plants and animals and can enter groundwater from fertilizers or animal and human waste. In Wisconsin, nitrate is one of the most common groundwater contaminants.

High nitrate levels are linked with some birth defects. Infants who consume drinking water with high nitrate levels are at risk of blue baby syndrome, a condition that limits the blood's ability to carry oxygen (WI DHS).



Arsenic contamination is most common in northeastern WI, regions 1 & 3 (WI DNR).

Arsenic and Nitrate testing results above EPA standards in Private Wells



Arsenic (As):

Percent of test results above EPA standard of 10 µg/L

Nitrate (NO₃⁻):

Percent of test results above EPA standard of 10 mg/L (WI DHS, 2024)

Thriving Natural World



Air Quality

Air pollution is the presence of one or more contaminants in the atmosphere, such as dust, fumes, gas, mist, odor, smoke, or vapor, in quantities and duration that can be injurious to human health.

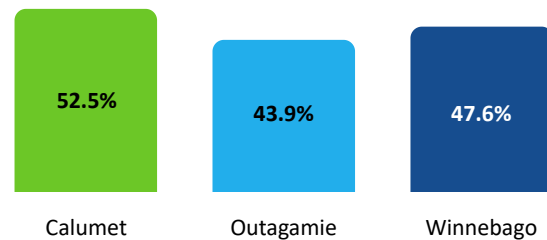
The main pathway of exposure from air pollution is through the respiratory tract. Breathing in these pollutants impacts the lungs, heart, and brain, ultimately leading to disease (WHO).

Indoor Air Quality Threats: Radon

Radon is a naturally occurring gas released from the ground that is radioactive and can cause lung cancer. Radon can leak into homes and other buildings through cracks in the foundation.

Homes both old and new can have unsafe radon levels, and the only way to know if a home has high radon levels is to test for it.

Homes that tested for **Radon equal to or above the EPA standard** of 4 picoCuries/L



(Alpha Energy Labs, 2024)

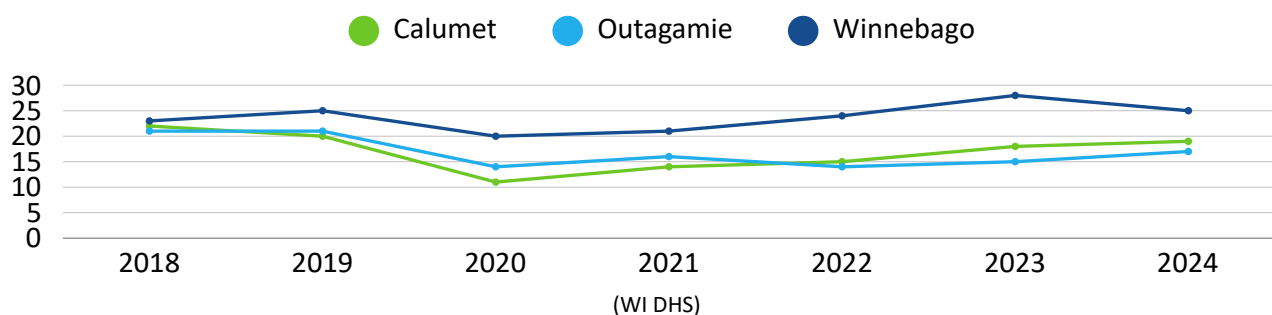
Outdoor Air Quality Threats: Pollution

- Most outdoor air pollution results from human activities, such as smoking, driving petroleum-powered vehicles, industrial operations, and burning wood, natural gas, or coal for electricity and heating and cooling buildings. Pollution can also come from natural sources, such as smoke from wildfires, dust, and dirt.
- Air quality is impacted by warmer temperatures and decreased precipitation, which makes it easier for outdoor air pollutants to form.
- Climate change is increasing temperatures in Wisconsin, lengthening the growing season for pollens and increasing the presence of allergens in the air from trees, grasses, weeds, and mold.

Who's at Risk from Air Pollution?

- People with existing health problems, such as asthma or other lung and heart diseases, are at greater risk of harmful health outcomes from air pollution.
- Children, older adults, pregnant women, and people who live or work outdoors for long periods of time or participate in intense exercise outdoors are more at risk of health issues from air pollution.
- Wildfire smoke can make anyone sick. Even someone healthy can get sick if there is enough smoke in the air.

Rate of **Emergency Department Visits for Asthma** (age-adjusted, per 10,000 people)



Thriving Natural World



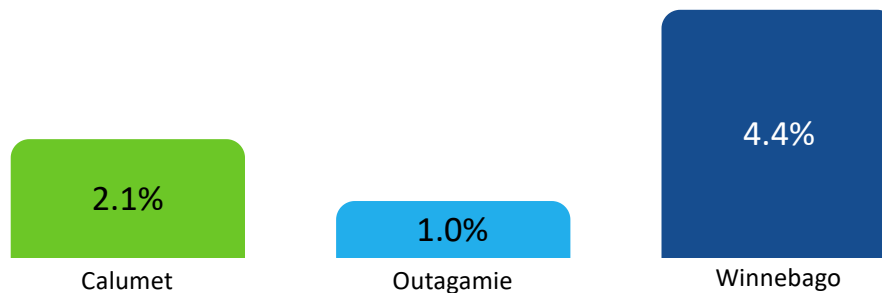
Lead Exposure

Lead is a naturally occurring metal that is toxic to humans when swallowed or inhaled. Lead was used in paint, plumbing materials, ceramics, gasoline, household products, batteries, and cosmetics. Children are most commonly exposed to lead through contact with chips and dust from old lead paint or from swallowing soil contaminated by lead paint, while adults are more likely to be exposed through inhalation of fumes or ingestion of dust or water contaminated by lead.

Childhood Lead Poisoning

No amount of lead exposure is safe for children. Exposure to lead damages the brain, body, and nervous system. Even at low levels, it affects learning capacity, ability to pay attention, and academic achievement. Lead is toxic to everyone, but children under age 6 are at greatest risk for harm because their bodies are still developing. Lead exposure for pregnant women is a particular concern because it can result in exposure to their developing baby (WI DHS).

Children with Lead Poisoning Aged Birth to <6



(WI DHS, 2024)

Note: The % of children is out of the number tested, not the number of total children in the county.

Childhood Lead Testing

In 2021, the CDC lowered the blood lead reference value in children from 5 µg/dL to 3.5 µg/dL. The Wisconsin Department of Health Services recommends testing for all children at ages 1 and 2 and any child aged 3-5 who hasn't been tested before.

Lead in Water

Lead can enter drinking water when plumbing materials that contain lead corrode, especially where the water has high acidity or low mineral content that corrodes pipes and fixtures. The most common sources of lead in drinking water are lead pipes, faucets, and fixtures. In homes with lead pipes that connect the home to the water main, also known as lead service lines, these pipes are typically the most significant source of lead in the water. Lead pipes are more likely to be found in older cities and homes built before 1986 (EPA).

Thriving Natural World



Changing Climate

Wisconsin is experiencing warmer winters, wetter springs, and more extreme weather events. The impact is wide-ranging; the economy, agriculture, infrastructure, including damage to roads and bridges, migration patterns, water levels, and water quality, ecosystems, and natural habitats (Wisconsin Initiative on Climate Change Impacts).

Warmer winters result in:

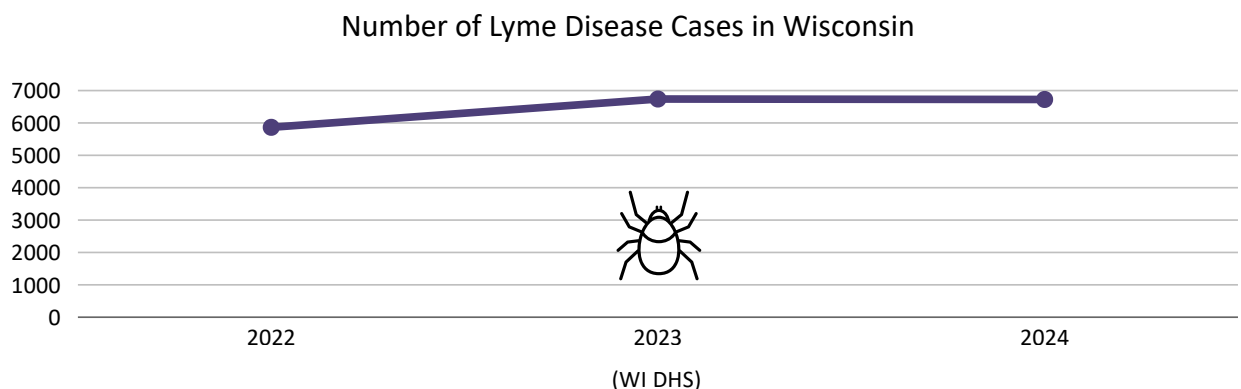
- Shrinking ice cover on lakes and rivers; fewer days with ice cover, and reduced overall thickness of ice (Larsen Converse).
- Reduced snowpack, which means less insulation for trees and other organisms.
 - Warmer temperatures allow pests to overwinter more successfully and migrate.
- Warmer water temperatures that change lake ecology. Cool-water fish like walleye will be found in fewer lakes, and warm-water fish like largemouth bass will be much more common.
- Precipitation shifting from snow to rain or freezing rain, limiting ice fishing, snowmobiling, snowshoeing, and skiing opportunities, impacting local restaurants, hotels, and taverns that depend on this winter recreation.

Wetter springs and more extreme weather events, specifically heavy rain, result in:

- Damage and reduced access to parks, beaches, lakes, rivers, and other natural resources.
- Flooding, eroding soil and coastlines, washing out roads and bridges, breaking dams, overwhelming sewers and wastewater treatment plants.
- Higher amounts of polluted runoff are impacting water quality, causing greater algae blooms.
- Reduced access to natural resources, limiting camping, hiking, fishing, boating, hunting, sightseeing, and other opportunities that typically draw people to our community.

Lyme Disease

Lyme disease is spread by the bite of an infected blacklegged tick and is becoming more common in Wisconsin. 2025 cases have already exceeded 2024 cases, though the year is not yet over. A warmer and wetter climate makes our state a favorable habitat for ticks. Climate change has contributed to the expanded geographic distribution of ticks as well as a longer season of tick activity and potential for Lyme disease transmission (WI DHS).



Thriving Natural World



How Did We Get Here?

In the 19th and early 20th centuries, Wisconsin's forests fueled logging booms and paper mills, while wetlands were drained for farms and towns. The Fox River became an engine of industrial growth, but was also contaminated by factory waste. Land was viewed mainly for production, not regeneration.

Minimal regulations, industrial growth, and large-scale farming operations contributed to economic growth. As communities grew, natural areas were replaced with subdivisions, streets, and parking lots, disturbing natural corridors and wetlands.

Ultimately, we are in this situation by prioritizing short-term growth over long-term balance. However, many solutions exist to restore our natural environment. Healing the land, restoring biodiversity, and ensuring people and nature thrive is possible.

Where We Are Today

Many have shifted their views of the natural world from exploitation of resources to protecting resources. Areas once heavily polluted, like the Fox River and our lakes, have undergone cleanup efforts (WI DNR).

The Tri-County region works to protect and celebrate its natural spaces. Parks, trails, and nature preserves provide places for residents to relax, exercise, and connect with the outdoors. These green spaces are vital not only for recreation but also for mental health and community well-being. Many local projects aim to make nature more accessible to everyone—like the High Cliff Connection, which links more neighborhoods to outdoor areas, and the ADRC's outdoor wheelchair program, which helps people with mobility challenges explore local trails.

Despite changing views, new proposals can damage the environment; the region faces pressure from outside states that want to draw water from the Great Lakes (Way). Local leaders and residents have stood strong in protecting this precious resource, ensuring it remains available for future generations.

Where Do We Go Next?

We all share responsibility for protecting our natural environment. Green infrastructure, forest buffers, and restored wetlands help communities adapt while supporting wildlife and recreation. Education and sustainable practices—like reducing plastic waste or planting native gardens—create lasting impact. Even simple acts, such as visiting local parks or walking along the Fox River, remind us why these places matter.

The Tri-County region's story is one of connection—between people and water, past and future, growth and responsibility. By working together and continuing to value our natural resources, we can ensure that the rivers, lakes, and parks that shaped our history will continue to shape our future in positive ways.

Health Behaviors

Health behaviors can be categorized on a spectrum from positive to negative. Positive health behaviors, such as regular exercise, healthy eating, and preventative healthcare visits, are associated with reduced risks of chronic diseases. Conversely, negative behaviors, like smoking, excessive alcohol consumption, and neglecting regular check-ups, contribute to the prevalence of various health issues.

Although it is undeniable that health can be influenced by individual choices, it is fundamental to understand that physical, social, and cultural environments have an outsized role in the decisions we make (Hook and Markus).

“*A culture-wide emphasis on personal choice and personal responsibility is harming Americans’ health and well-being.*”
(Hook and Markus)

The Role of Personal Choices in Health Behaviors

Despite constant calls for people to take responsibility for their health, **Americans die younger and experience more illnesses and injuries than their counterparts in other high-income countries.**

If the **United States spends the most on healthcare per person among developed countries** (Wager), why don’t we have the healthiest population?

“Personal choice” has been used to support a health care system that leaves the United States “alone among rich capitalist nations in not guaranteeing basic universal health coverage” and has allowed food, tobacco, and alcohol industry groups to resist regulation that would limit sales (Hook and Markus).

40% of deaths in the US are caused by chronic “lifestyle” diseases.

More than 70% of adults in the United States report at least one of five unhealthy behaviors associated with chronic health problems: **smoking, drinking excessively, obesity, getting insufficient sleep, and being physically inactive.** At greatest risk for poor health are the 25 million adults, or 12% of the adult population, with three or more such behaviors (America’s Health Rankings).

Improving health requires policies and strategies that make healthy behaviors easy.

The reason Americans die younger and are sicker is because personal responsibility is not the right strategy to improve health. While many chronic diseases and deaths associated with lifestyle are preventable, a more effective approach is to focus on policies that have a broad reach, impacting entire populations.

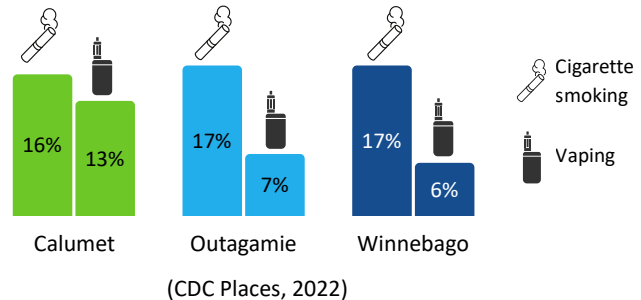
Health Behaviors

Smoking and Vaping

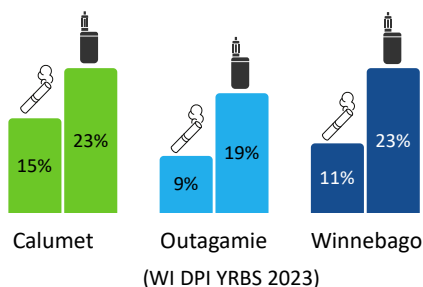
- Smoking harms nearly every organ in the body and increases the risk of heart disease, stroke, lung disease, and many types of cancer.
- Tobacco and nicotine disproportionately burden Black, Native/Indigenous, Hispanic, and LGBTQ+ communities, people with low incomes or educational attainment, and people in mental health or substance use treatment (WI DHS).

The word "tobacco" on this page refers to commercial tobacco, not traditional Native American/Indigenous tobacco.

Adult cigarette and vaping rates



High school students who report they have tried smoking cigarettes and vaping



Tobacco Industry Influence in Wisconsin

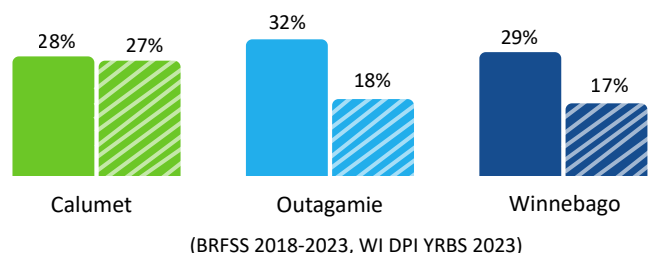
The tobacco industry has a long history of targeting teenagers in its effort to establish lifelong customers.

- Annual tobacco industry marketing expenditures nationwide are \$8.6 billion, with \$161.2 million spent annually in WI.
- Kids are more likely to be influenced to smoke by cigarette marketing than by peer pressure.
- One third of underage experimentation with smoking is attributable to tobacco company advertising (Campaign for Tobacco Free Kids).

Alcohol Use

Binge drinking is consuming 5 or more drinks for males, 4 or more drinks for females in about 2 hours. Underage drinking is a persistent challenge, often with serious consequences including motor vehicle crashes, violence, sexual assault, suicide, poor school performance and increased risk of developing an alcohol use disorder.

Binge drinking among adults; High school students who report they drank in the last 30 days



Bars with solid color: Adults Bars with lines: High School Students

- Wisconsinites in every age group engaged in more binge drinking than the US median for that age group (WI DHS).
- Wisconsinites ages 25-44 had the highest proportion of binge drinkers.
- Among adults in Wisconsin who binge drink, 25% consume at least 9 drinks per binge-drinking occasion (BRFSS, 2022).

Health Behaviors

Poor Diet

Ultraprocessed foods (UPF) are industrial creations made with little—if any—whole foods and often contain large amounts of added sugar and salt.

Such food now **accounts for nearly 60% of U.S. adults’ calorie consumption. Among American children, that portion is close to 70%.** In other words, ultra-processed food is starting to overwhelm the American diet.

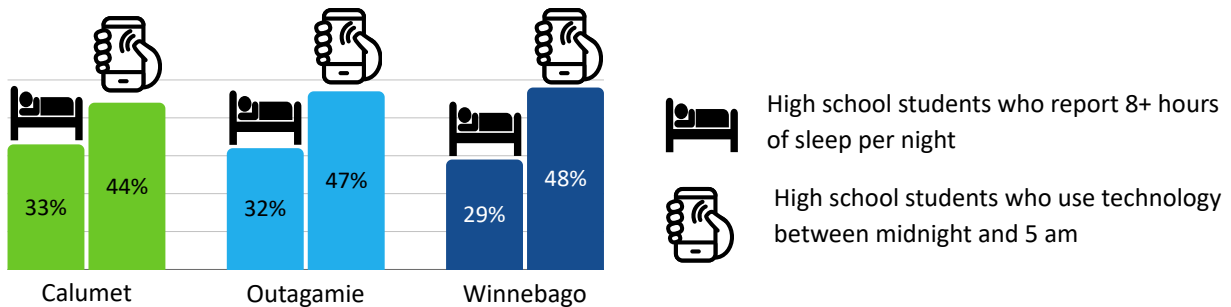
Diets high in UPF increase risk for chronic diseases:

- **Obesity**
- **Type 2 Diabetes**
- **Heart Disease**
- **Cancer** (Berg)

Sleep

Getting adequate sleep is critical for our emotional and physical well-being. The amount of sleep recommended varies by age. Teens between the ages of 13-17 should get 8-10 hours a night, while adults should get at least 7 hours. It is recommended to turn off electronic devices at least 30 minutes before bedtime, to avoid caffeine in the afternoon and evening, and to exercise regularly and maintain a healthy diet (CDC).

The more high school students use technology at night, the less likely they are to get 8+ hours of sleep.



(WI DPI YRBS 2023)

Help-Seeking Behaviors

Help-seeking behavior can be defined as a person “searching for or requesting help from others via formal or informal mechanisms” (APA). It can include seeking out mental health services, receiving help from a friend or family member, or utilizing online services such as communities, forums, or chats.

- 85% of Mind Your Wellness Survey respondents (2022) reported feeling comfortable discussing mental health issues with others.
- A majority of the respondents, though, reported seeking help for mental health issues from a friend or family member as opposed to a mental health professional.
- The lower a person’s income, the less aware they appear to be of how to access mental health care and they are more likely to keep their concerns to themselves.

Health Behaviors

Food insecurity frequently indicates low income, insufficient to consistently afford adequate and nutritious food (Healthy People 2030). The table below uses food insecurity data to show how students in our community generally make worse health decisions when they come from low-income households. These students' behaviors don't lead to the financial situation of their households. Instead, these data show how **inadequate systems and financial barriers lead to less healthy behaviors**. Food insecurity is self-reported.

Example of how to read the data table:

- 80% of Calumet County high school students who identified as food insecure wear their seatbelt most of the time or always.
- 88% of Calumet County high school students who did not identify as food insecure wear their seatbelt most of the time or always.

Health Behaviors Broken Down by Food Insecurity

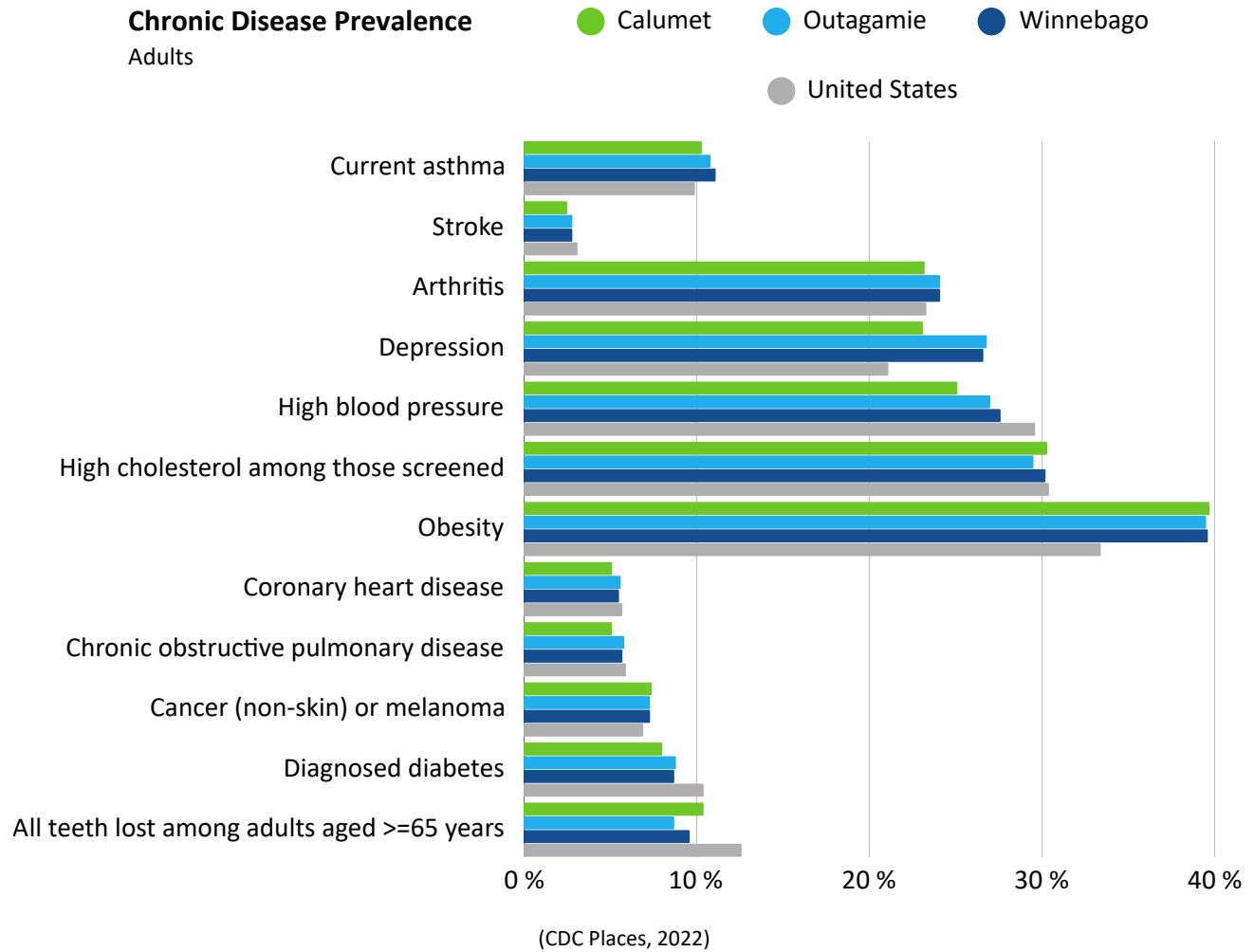
	Calumet High School Students		Outagamie High School Students		Winnebago High School Students	
	Food Insecure	Not Food Insecure	Food Insecure	Not Food Insecure	Food Insecure	Not Food Insecure
Most of the time or always wear a seatbelt	80%	88%	82%	94%	83%	92%
Slept 8 or more hours per night	21%	35%	23%	34%	20%	31%
Used a condom during last sexual intercourse	66%	63%	57%	68%	53%	68%
Rode with a driver who drank	23%	16%	21%	11%	20%	10%
Ever tried cigarettes	24%	13%	17%	7%	20%	8%
Ever tried vaping	34%	20%	30%	16%	38%	19%
Ever misused a prescription pain medicine	17%	5%	14%	5%	14%	5%

(WI DPI YRBS 2023)

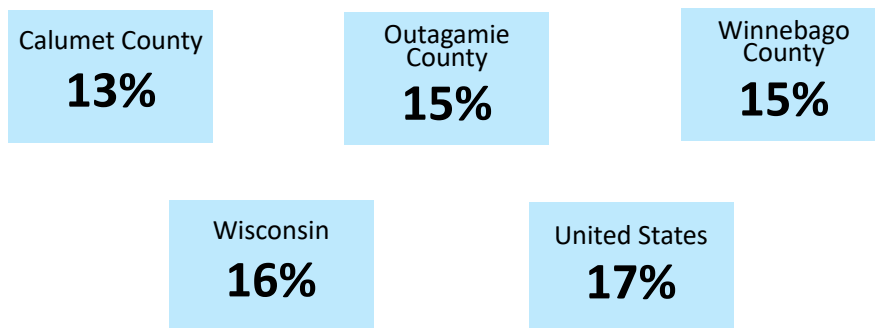
Health Outcomes

Morbidity

The state of being symptomatic or unhealthy for a disease or condition, or the amount of disease within a population.



Percent of Adults Reporting Fair or Poor Health, 2022



(County Health Rankings)

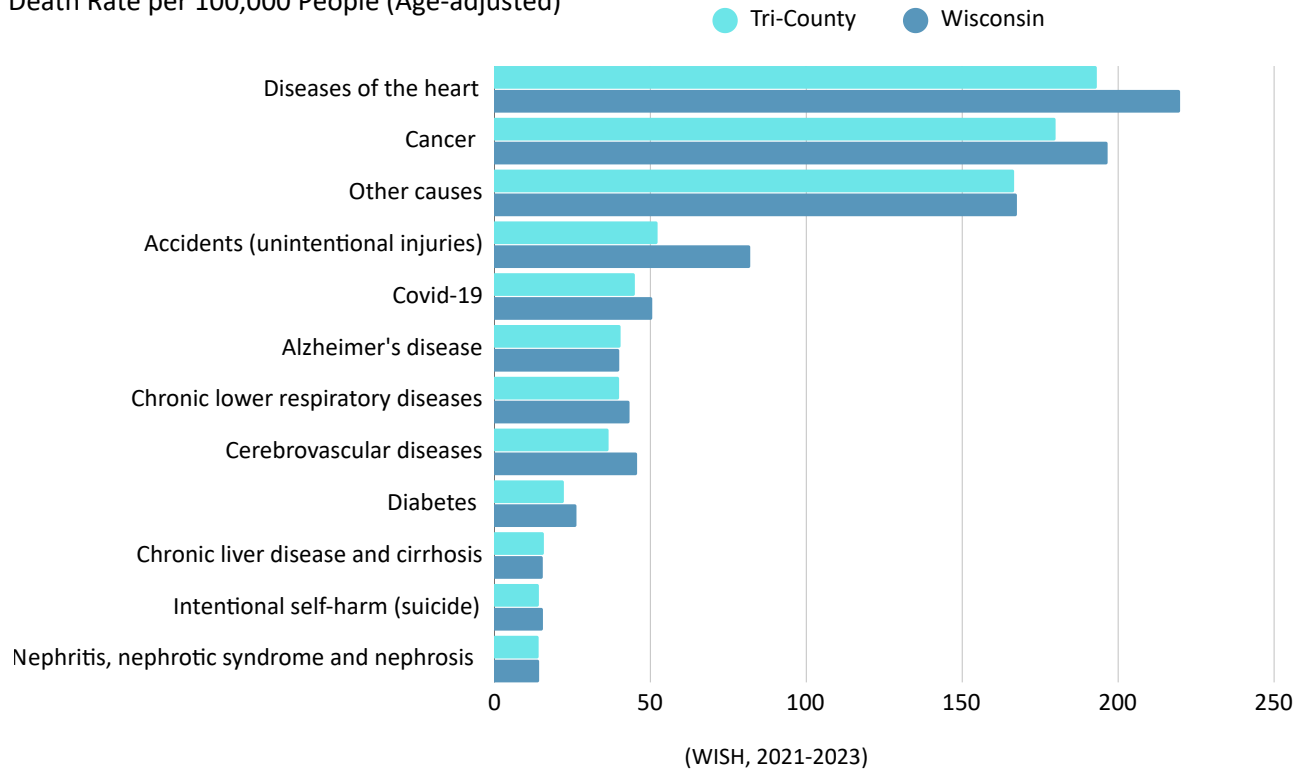
Health Outcomes

Mortality

The measure of the frequency of occurrence of death in a defined population during a specified interval of time.

Top Causes of Death

Death Rate per 100,000 People (Age-adjusted)



Infant Mortality Child Mortality

Number of deaths among children under 1 year of age Number of deaths among persons under 20 years of age

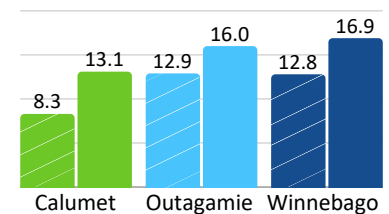
	Deaths per 1,000 Live Births	Deaths per 100,000 Children
Wisconsin	5.5	50
Calumet	2.9	30
Outagamie	3.4	50
Winnebago	4.7	50

(WISH, 2023)

Unintentional Drug Overdose

Deaths and Suicide Deaths

Death Rate per 100,000 People in 2024



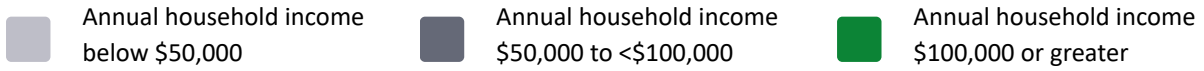
▨ Bars with lines: Unintentional Drug Overdose
 ■ Bars solid color: Suicide

For Calumet County, rates are modeled to protect privacy because number is low (1-9)

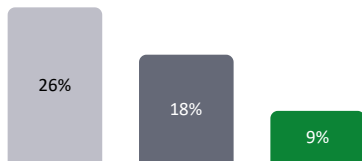
(CDC)

Health Outcomes

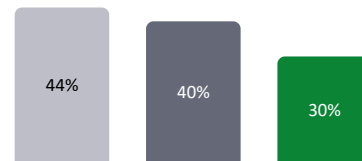
Wealth consistently correlates with the vital conditions for health and well-being. People with greater wealth generally have access to better vital conditions. This leads to better health outcomes overall. The graphs below are data specifically collected from residents of Calumet, Outagamie, and Winnebago Counties in 2024 (BRFSS 2024). The data show that Tri-County residents in households with annual income above \$100,000 have better health outcomes than those in households with annual income below \$50,000.



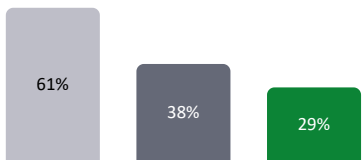
High-income residents are less likely to have ever had diabetes.



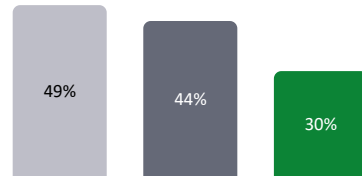
High-income residents are less likely to be obese.



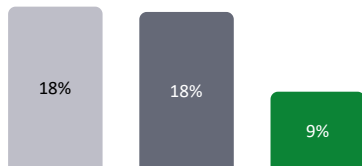
High-income residents are less likely to have ever had any adult teeth removed.



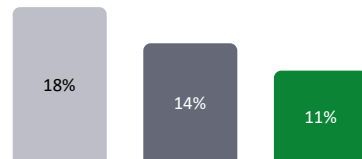
High-income residents are less likely to have developed arthritis.



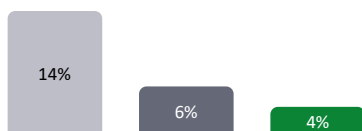
High-income residents are less likely to have ever had melanoma or another cancer.



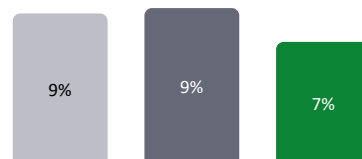
High-income residents are less likely to have ever been diagnosed with asthma.



High-income residents are less likely to have ever had COPD, emphysema, and/or chronic bronchitis.

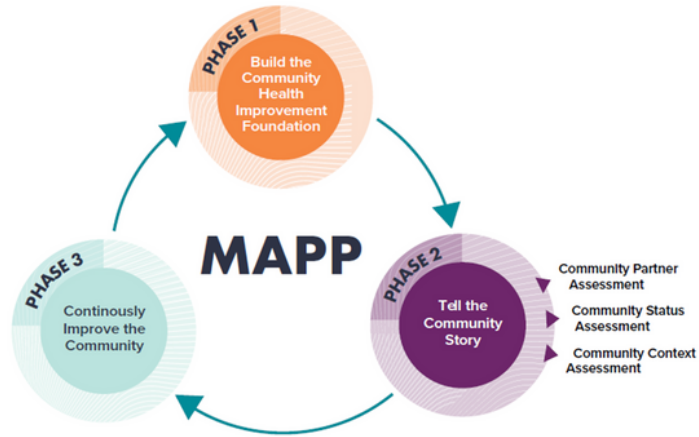


High-income residents are less likely to have ever had angina or coronary heart disease.



Assessment Results - Purpose & Process

MAPP 2.0 is a 3-phase process. The Coalition started with Phase 2; Tell the Community Story, completing 3 different assessments (Sept.-Nov. 2024). The Coalition used the results of these assessments to inform the prioritization process for its Community Health Improvement Plan.



Community Partner Assessment

The Coalition sent a survey to more than 400 community organizations to understand what topics they were working on, where they operated, and whether they might be interested in joining the Coalition’s efforts. Roughly 130 organizations responded.

Community Context Assessment

The Coalition analyzed 21 existing reports from community listening sessions and focus groups to understand community members’ views on what is influencing their health and well-being. The Coalition looked at the information to identify strengths and weaknesses.

Community Status Assessment

The Coalition compiled existing metrics on vital community conditions, health and well-being behaviors, and health outcomes, a for Winnebago, Calumet, and Outagamie Counties, as well as Wisconsin and the U.S.

Data Triangulation & Data Placemats

Jan. 7-30, 2025: The Coalition held biweekly meetings to discuss findings through a data triangulation process. Topics were based on the Vital Conditions plus health behaviors and health outcomes. “Data placemats” were developed from the 3 assessments for each topic.

Sense-Making & Community Input

The Coalition identified 8 topics to share with community organizations for further discussion and prioritization. Topics were viewed as the most pressing, impactful on other vital conditions, and possible for the Coalition to address. During a day-long, in-person prioritization meeting on Feb. 11, 2025, the Coalition and 30 community organizations narrowed the list of 8 topics down to 3.

Prioritization

Community experts then presented data and context about the remaining 3 topics. With this information the Coalition narrowed its focus to 2 priorities: Mental Health and Belonging & Civic Muscle. These will be the focus of this cycle’s Community Health Improvement Plan. The third community priority - Humane Housing - was not selected because community housing experts are already leading an ongoing effort to address this topic area.

Collaboration & Next Steps

Community Health Improvement Plan (CHIP)

Next steps include identifying the priority health focus areas that will make up the Community Health Improvement Plan. These focus areas will be identified using the provided information found in this Community Health Assessment.

This collaborative process began in earnest in 2022 with representatives from each of the 5 Tri-County Public Health agencies: David DeGroot (Outagamie), Cathy Ellis (Calumet), Claire Holzschuh (Menasha), Heidi Keating (Winnebago), and Chuck Sepers (Appleton). These 5 individuals spent months discussing how to be more respectful of community partners' time, more efficient with organizational resources, and more intentional about aligning plans and programs. The charter they wrote served as the foundation for this work.

With the addition of health care systems and community organizations in 2023, the Tri-County Community Health Improvement Coalition was formed to ensure that everyone in the region has a fair and just opportunity to achieve health and well-being. The health data included in this assessment from Calumet, Outagamie, and Winnebago Counties will provide the Coalition with information to identify priority health areas that will be focused on during the 3-year community health improvement cycle. Additionally, the coalition identified a vision and mission to follow as a result of the community health assessment process.

Vision: A unified, repeatable community health improvement process – with shared language, learning, plans, and progress.

Mission: To engage diverse community stakeholders to analyze community health, prioritize opportunities, implement evidence-informed strategies, and measure progress toward improving well-being for all.

A standard community health improvement plan typically includes 1 to 3 priority health areas. These health areas are community-focused and are identified during the community health assessment process. Each priority health area will have measurable objectives, strategies, and activities. These measures are important to ensure that the community efforts are having the intended outcome. They also provide ongoing feedback to determine if strategies may need to be altered or changed. This follows the MAPP framework, where planning, implementing, and evaluation are consistently occurring during the 3-year health improvement plan cycle.

Lastly, a key component of the community health improvement plan is the community itself. Community support work will be conducted by the Coalition, local stakeholders, and regional partners over the next 3 years to help the Tri-County Community Health Improvement Coalition improve well-being for all.

THANK YOU

The Coalition extends a big “Thank You” to all of the community organizations that provided input into the prioritization of topics and issues. These organizations have expressed willingness to partner with the Coalition and mobilize their resources to address community needs. The list below is not exhaustive.

-
- | | |
|---|--|
| ABC for Health, Inc. | Lawrence University |
| ADVOCAP, Inc. | Local faith-based communities |
| Apricity | Local libraries |
| Big Brothers Big Sisters of East Central Wisconsin | Lutheran Social Services of Wisconsin & Upper Michigan |
| Boys & Girls Clubs | NAMI Fox Valley, Inc. |
| Building for Kids Children’s Museum | NeighborWorks Green Bay |
| Celebrate Diversity Fox Cities | Oneida Nation |
| Community Foundation for the Fox Valley Region | Oshkosh Area Community Pantry |
| East Central Wisconsin Regional Planning Commission | Pillars, Inc. |
| ESTHER Fox Valley | Pointtters Community Initiatives |
| Family Services of Northeast Wisconsin | Rainbow Alliance Advocacy |
| Father Carr’s Place 2B | Reach Counseling |
| Feeding America Eastern Wisconsin | Rogers Behavioral Health |
| First 5 Fox Valley | Salvation Army |
| Fox Valley Veterans Council, Inc. | School districts |
| Greater Fox Cities Area Habitat for Humanity | Tri-County Dental |
| Greater Oshkosh Health Neighborhoods, Inc. | Us 2 Behavioral Health Care |
| Hope Clinic & Care Center | Valley Packaging Industries |
| Independent Care Health Plan | Vivent Health |
| JKV Research, LLC | World Relief |

Another big “Thank You” to all of the Coalition member organizations and their staff for their commitment to this project and the health of the people they serve:

- | | |
|---------------------------------------|-------------------------------------|
| Ascension | NEW Hmong Professionals |
| Aurora Health Care | NEW Mental Health Connection |
| Calumet County Public Health | Outagamie County Public Health |
| Casa Hispana | Partnership Community Health Center |
| Children’s Wisconsin | People of Progression |
| City of Appleton Health Department | Samaritan Fox Valley |
| City of Menasha Health Department | ThedaCare |
| Diverse and Resilient | United Way Fox Cities |
| Fox Valley Data Exchange | Winnebago County Public Health |
| Hmong American Partnership Fox Valley | YMCA of Fox Cities |

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“

Throughout the document, the text in these graphics represents quotes from Tri-County community members gathered via surveys, listening sessions, and focus groups.

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DEPARTMENT OF
**LEGAL AND
ADMINISTRATIVE
SERVICES**

CITY ATTORNEY'S OFFICE
100 North Appleton Street
Appleton, WI 54911
p: 920.832.6423
www.appletonwi.gov

TO: Dr. Charles Sepers, Health Officer

FROM: Darrin Glad, Assistant City Attorney *D. Glad*

DATE: June 30, 2026

RE: Limitations on Municipal Authority to Regulate Vehicular
Noise Under Wisconsin Law
Our File No. A26-0277

I. Introduction

This memorandum examines the scope of municipal authority to regulate vehicular noise under Wisconsin law. Specifically, it analyzes the limitations imposed by the state motor vehicle code and the conditions under which local traffic regulations are permissible. The primary statutory framework consists of Wis. Stat. § 347.39 (vehicle muffler and exhaust requirements), Wis. Stat. § 349.03 (prohibition on local traffic regulations inconsistent with state law), and Wis. Stat. § 349.06 (authorizing local traffic regulations in strict conformity with state law). The conclusion is that municipalities possess limited authority to regulate vehicular noise. While the City cannot enact ordinances that conflict with or exceed the scope of state muffler and exhaust regulations, the City retains the power to regulate noise-generating driving conduct not addressed by the motor vehicle code, such as noise caused by squealing tires or excessive acceleration. Any local regulation of vehicular equipment, including mufflers and exhaust systems, must be in strict conformity with state law.

II. Statement of Facts

An email from Ald. Smith dated June 8, 2026 attached a memo from the Wisconsin Legislative Reference Bureau (“WLRB”), which Ald. Smith alleges states that local regulation of vehicular noise is possible if a vehicle exceeds the pure noise limits set by ordinance without regard to the source of the noise, i.e., an operator of a vehicle can be cited purely for the fact that the vehicle exceeds noise limits notwithstanding any specific issues related to mufflers. (WLRB memo). Ald. Smith’s summary of the WLRB memo is misleading. Accordingly, a more detailed analysis of current law, Appleton Municipal Code, and the WLRB memo follows.

Importantly, Appleton Municipal Code already regulates vehicular noise. In particular, Sections 19-1 and 12-80(g) of the Municipal Code of the City of Appleton adopt state laws regulating muffler noise while Section 12-80(h) goes further by prohibiting any operator of a motor vehicle from accelerating in “such a manner as to create unnecessary noise, including but not limited to loud or excessive engine revving, tire squealing caused by friction with the roadway surface, or causing tires to throw stones or gravel while accelerating.” This analysis addresses the legal boundaries of such local regulation under Wisconsin’s statutory framework.

III. Legal Standards

A. *State Motor Vehicle Code Requirements for Mufflers and Exhaust Systems*

Wisconsin law establishes mandatory equipment standards for motor vehicles operating on public highways. Wis. Stat. § 347.39(1) requires that every motor vehicle subject to registration be “equipped with an adequate muffler in constant operation and properly maintained to prevent any excessive or unusual noise or annoying smoke.” Wis. Stat. § 347.39. The statute prohibits the use of cutouts, bypasses, or similar devices on mufflers or exhaust systems, and it forbids devices that ignite exhaust gases to produce flame. Wis. Stat. § 347.39. Section 347.39(2) further provides that no person shall “modify the exhaust system of any such motor vehicle in a manner which will amplify or increase the noise emitted by the motor of such vehicle above that emitted by the

muffler originally installed on the vehicle.” Wis. Stat. § 347.39. These provisions create a comprehensive state regulatory scheme governing vehicular exhaust systems and muffler equipment. The original muffler installed on the vehicle serves as the baseline noise standard, and any modification that increases noise beyond that baseline is prohibited. Wis. Stat. § 347.39.

B. Preemption of Local Traffic Regulations Under Section 349.03

Wisconsin’s motor vehicle code establishes a uniform statewide regulatory system. Wis. Stat. § 349.03(1) provides that chapters 341 to 348 and 350 “shall be uniform in operation throughout the state.” Wis. Stat. § 349.03. The statute expressly prohibits local authorities from enacting or enforcing any traffic regulation unless the regulation either “(a) [i]s not contrary to or inconsistent with chs. 341 to 348 and 350; or (b) [i]s expressly authorized by ss. 349.06 to 349.25 or some other provision of the statutes.” Wis. Stat. § 349.03. Section 349.03(2) further restricts local authority by prohibiting traffic regulations that “in any manner exclud[e] or prohibit[] any motor vehicle ... whose owner has complied with chs. 341 to 348 from the free use of all highways” except as specifically authorized by statute. Wis. Stat. § 349.03. This provision protects the rights of vehicle owners who have complied with state registration and equipment requirements to use public highways without additional local restrictions. The Wisconsin Supreme Court has interpreted § 349.03 to establish strict limits on municipal traffic regulations. In City of Janesville v. Garthwaite, the court explained that local traffic regulations are valid only if they are “not contrary to or inconsistent with state statutes or are expressly authorized by secs. 349.06 to 349.25.” Janesville v. Garthwaite, 83 Wis. 2d 866, 266 N.W.2d 418 (1978). The court emphasized that while the ordinance under review did not “authorize what is expressly prohibited by statute,” the proper test is whether the ordinance “exceeds...and forbids in an area preempted by the state, in order to have uniformity, what the state law does not forbid.” Janesville v. Garthwaite, 83 Wis. 2d 866, 266 N.W.2d 418 (1978).

C. Authorization for Local Traffic Regulations Under Section 349.06

Section 349.06 provides the primary mechanism by which municipalities may enact local traffic regulations. Wis. Stat. § 349.06(1)(a) authorizes any local authority to “enact and enforce any traffic regulation which is in strict conformity with one or more provisions of chs. 341 to 348 and 350 for which the penalty for violation thereof is a forfeiture.” Wis. Stat. § 349.06. The statute also permits local regulations “in strict conformity with any rule of the department promulgated under ch. 110, 347 or 348.” Wis. Stat. § 349.06. The requirement of “strict conformity” is significant. Local regulations must replicate state law provisions without variation or modification. Traffic regulations adopted by local authorities that “incorporate by reference existing or future amendments to chs. 340 to 348 or rules of the department” are deemed to be in strict conformity and not contrary to or inconsistent with state law. Wis. Stat. § 349.06.

D. The Garthwaite Exception: Regulation of Noise-Generating Conduct Not Addressed by the Motor Vehicle Code

In City of Janesville v. Garthwaite, the Wisconsin Supreme Court considered whether a city ordinance prohibiting “unnecessary and annoying noise” from squealing tires or excessive acceleration violated § 349.03. Janesville v. Garthwaite, 83 Wis. 2d 866, 266 N.W.2d 418 (1978). The court held that the ordinance was a valid exercise of municipal police power because it regulated conduct not addressed by the motor vehicle code. Janesville v. Garthwaite, 83 Wis. 2d 866, 266 N.W.2d 418 (1978). The court reasoned that although the motor vehicle code regulates horn and muffler noise, it does not regulate noise caused by squealing tires or excessive engine acceleration. Janesville v. Garthwaite, 83 Wis. 2d 866, 266 N.W.2d 418 (1978). Because “the state motor vehicle code does not address noise from squealing tires or engine acceleration,” the local ordinance was “neither inconsistent with nor contrary to the code.” Janesville v. Garthwaite, 83 Wis. 2d 866, 266 N.W.2d 418 (1978). The court distinguished cases where municipalities attempted to regulate in areas already occupied by state law, emphasizing that the ordinance at

issue addressed “a local traffic regulation and a nonstatute, with legislative silence on the subject.” Janesville v. Garthwaite, 83 Wis. 2d 866, 266 N.W.2d 418 (1978). Garthwaite affirmed that municipalities retain authority under Wis. Stat. § 62.11(5) to manage and control highways and enact regulations for public health, safety, and welfare, except as elsewhere provided in the statutes. Janesville v. Garthwaite, 83 Wis. 2d 866, 266 N.W.2d 418 (1978). This residual police power permits local regulation of vehicular conduct that generates noise through operational means (such as tire squealing or aggressive acceleration) rather than through defective or modified equipment.

E. General Principles of Municipal Home Rule and Preemption

Wisconsin municipalities possess broad home rule authority under Article XI, section 3(1) of the Wisconsin Constitution and Wis. Stat. § 62.11(5). Apartment Ass’n of S. Cent. Wis., Inc. v. City of Madison, 2006 WI App 192, 296 Wis. 2d 173, 722 N.W.2d 614. Cities and villages have the power “to determine their local affairs and government, subject only to this constitution and to such enactments of the legislature of statewide concern as with uniformity shall affect every city or village.” Apartment Ass’n of S. Cent. Wis., Inc. v. City of Madison, 2006 WI App 192, 296 Wis. 2d 173, 722 N.W.2d 614. The legislature has granted cities broad powers such that they “possess all powers not denied them by the statutes or the constitution.” Wisconsin’s Env’tl. Decade, Inc. v. Dep’t of Nat. Res., 85 Wis. 2d 518, 271 N.W.2d 69 (1978). However, a municipality’s ability to regulate matters of statewide concern is limited. Apartment Ass’n of S. Cent. Wis., Inc. v. City of Madison, 2006 WI App 192, 296 Wis. 2d 173, 722 N.W.2d 614. When the state legislates on a matter of statewide concern, it preempts a local ordinance if any of the following four conditions exist: “(1) the legislature has expressly withdrawn the power of the municipality to act; (2) the ordinance logically conflicts with the state legislation; (3) the ordinance defeats the purpose of state legislation; or (4) the ordinance violates the spirit of the state legislation.” Apartment Ass’n of S. Cent. Wis., Inc. v. City of Madison, 2006 WI App 192, 296 Wis. 2d 173, 722 N.W.2d 614. If any one of these tests is met, the municipal ordinance is void. Apartment Ass’n of S. Cent. Wis., Inc. v.

City of Madison, 2006 WI App 192, 296 Wis. 2d 173, 722 N.W.2d 614. An ordinance enacted under § 62.11(5) is valid unless “there is express language elsewhere in the statutes restricting, revoking, or withdrawing the power, or unless state legislation is logically inconsistent with the existence of the power in the city.” Anchor Sav. & Loan Asso. v. Equal Opportunities Com., 120 Wis. 2d 391, 355 N.W.2d 234 (1984). Additionally, ordinances may not “infringe the spirit of a state law or ... general policy of the state.” Anchor Sav. & Loan Asso. v. Equal Opportunities Com., 120 Wis. 2d 391, 355 N.W.2d 234 (1984). The principle announced in Fox v. Racine remains controlling: “where ‘the state has entered the field of regulation, municipalities may not make regulation inconsistent therewith’ because ‘a municipality cannot lawfully forbid what the legislature has expressly licensed, authorized or required, or authorize what the legislature has expressly forbidden.’” DeRosso Landfill Co. v. City of Oak Creek, 200 Wis. 2d 642, 547 N.W.2d 770 (1996) quoting Fox v. Racine, 225 Wis. 542, 546, 275 N.W. 513 (1937).

IV. Analysis

A. Municipal Regulation of Vehicular Equipment Is Preempted by Section 347.39

The state has comprehensively occupied the field of vehicular equipment regulation, including mufflers and exhaust systems. Section 347.39 establishes mandatory statewide standards for mufflers, prohibits specific modifications, and sets the baseline noise level at the original manufacturer’s muffler. Wis. Stat. § 347.39. These provisions reflect a legislative determination to ensure uniform equipment requirements across the state. Under § 349.03(1), local authorities may not enact traffic regulations that are “contrary to or inconsistent with” the motor vehicle code unless expressly authorized. Wis. Stat. § 349.03. Any municipal ordinance that imposes stricter muffler standards, establishes different noise limits for exhaust systems, or prohibits modifications beyond those forbidden by § 347.39 would exceed state law and violate the uniformity requirement. Such an ordinance would “forbid[] in an area preempted by the state, in order to have uniformity, what the state law does not forbid,” and would therefore fail the strict conformity test. Janesville v. Garthwaite, 83 Wis. 2d 866, 266 N.W.2d 418 (1978). A local

ordinance that permits equipment or modifications prohibited by § 347.39 would conflict with state law.

A municipality “cannot lawfully forbid what the legislature has expressly licensed, authorized or required, or authorize what the legislature has expressly forbidden.” DeRosso Landfill Co. v. City of Oak Creek, 200 Wis. 2d 642, 547 N.W.2d 770 (1996). Because the legislature has expressly authorized motor vehicles to operate on highways with properly functioning mufflers, Appleton cannot regulate vehicular noise inconsistent with Wis. Stat. § 347.39. Any ordinance that prohibits vehicular noise above a certain decibel level would be void because the legislature has expressly authorized motor vehicles to operate on highways with properly functioning mufflers and any limit on decibel levels ignores the lawfulness of such operation.

The City may, however, enact a local ordinance in strict conformity with § 347.39. Under § 349.06(1)(a), the City is authorized to adopt and enforce traffic regulations that replicate state law provisions verbatim. Wis. Stat. § 349.06. Such an ordinance would allow local enforcement of the state muffler standard but would not expand or contract the scope of prohibited conduct. Appleton has done just that in adopting Wis. Stat. § 347.39 in Sections 19-1 and 12-80(g) and therefore has an enforceable framework for enforcement in this area.

B. Municipal Regulation of Noise-Generating Driving Conduct Remains Permissible Under Garthwaite

While the City cannot regulate vehicular equipment beyond the bounds set by § 347.39, it retains authority to regulate driving conduct that generates noise through operational means rather than defective equipment. The Wisconsin Supreme Court’s decision in City of Janesville v. Garthwaite establishes that municipalities may regulate noise caused by squealing tires because such conduct is not addressed by the motor vehicle code. Janesville v. Garthwaite, 83 Wis. 2d 866, 266 N.W.2d 418 (1978). The Garthwaite court distinguished between regulations governing the same conduct already regulated by state law and regulations addressing matters on which the

legislature has remained silent. Janesville v. Garthwaite, 83 Wis. 2d 866, 266 N.W.2d 418 (1978). Because the motor vehicle code regulates muffler and horn noise but does not address tire squealing or aggressive acceleration, a local ordinance prohibiting “unnecessary and annoying noise” from such conduct does not conflict with or contradict the state regulatory scheme. Janesville v. Garthwaite, 83 Wis. 2d 866, 266 N.W.2d 418 (1978). This principle reflects the continued vitality of municipal police power under § 62.11(5). Cities possess express authority to manage and control highways and enact regulations for public health, safety, and welfare except as elsewhere provided in the statutes. Janesville v. Garthwaite, 83 Wis. 2d 866, 266 N.W.2d 418 (1978). Where the state has not legislated on a particular aspect of vehicular conduct, municipalities may regulate that conduct pursuant to their general police powers, provided the regulation does not logically conflict with or defeat the purpose of state law.

Applying Garthwaite, the City may enact ordinances prohibiting driving behaviors that generate excessive or unnecessary noise, such as tire squealing from rapid acceleration or deceleration, aggressive “revving” of engines while stationary, or prolonged idling that creates noise disturbances. Such regulations would target the manner of vehicle operation rather than the equipment itself, and would address a gap in the state regulatory framework. However, any such ordinance must be carefully drafted to avoid indirect regulation of equipment. For example, an ordinance that prohibits “any vehicular noise exceeding ‘X’ decibels” would effectively impose stricter muffler standards than § 347.39 and would be preempted. In contrast, an ordinance prohibiting “unnecessary noise caused by squealing tires, excessive acceleration, or aggressive engine revving” regulates conduct and falls within the Garthwaite exception. **Appleton has already adopted an ordinance prohibiting any operator of a motor vehicle from accelerating in “such a manner as to create unnecessary noise, including but not limited to loud or excessive engine revving [and] tire squealing caused by friction with the roadway surface” in Section 12-80(h) and therefore has an enforceable framework for enforcement in this area.**

C. The City Cannot Exclude Compliant Vehicles from Public Highways

Section 349.03(2) provides additional protection for vehicle owners who comply with state law. The statute prohibits local authorities from enacting traffic regulations “in any manner excluding or prohibiting any motor vehicle, whose owner has complied with chs. 341 to 348 from the free use of all highways” except as specifically authorized by statute. Wis. Stat. § 349.03. This provision would be implicated if the City attempted to ban certain classes of vehicles (such as motorcycles or modified vehicles) based on noise concerns, even if those vehicles meet the equipment requirements of § 347.39. A vehicle whose owner has complied with state registration and equipment standards, including the muffler requirements of § 347.39, cannot be categorically excluded from city streets based on noise characteristics, absent express statutory authorization. Such an ordinance would directly conflict with § 349.03(2). The City's authority is further constrained by the principle that it “cannot lawfully forbid what the legislature has expressly licensed, authorized or required.” DeRosso Landfill Co. v. City of Oak Creek, 200 Wis. 2d 642, 547 N.W.2d 770 (1996). **If a vehicle is equipped with a muffler that complies with § 347.39, Appleton cannot prohibit its operation solely on the basis that the vehicle generates more noise than the City prefers (i.e., strict decibel level ordinance), as this would constitute an indirect equipment regulation that exceeds state standards.**

V. Conclusion

Wisconsin law imposes significant limitations on municipal authority to regulate vehicular noise. The state has comprehensively regulated vehicular equipment, including mufflers and exhaust systems, through Wis. Stat. § 347.39. Wis. Stat. § 347.39. Under Wis. Stat. § 349.03, local ordinances may not be contrary to or inconsistent with the motor vehicle code unless expressly authorized. Wis. Stat. § 349.03. Municipalities may adopt ordinances in strict conformity with state equipment standards under Wis. Stat. § 349.06(1)(a), but they cannot impose stricter or different muffler requirements. Wis. Stat. § 349.06. However, the City retains authority to regulate noise-

generating driving conduct not addressed by the motor vehicle code. Under City of Janesville v. Garthwaite, municipalities may prohibit unnecessary and annoying noise caused by squealing tires, excessive acceleration, or similar operational conduct, as such regulations address matters on which the state has not legislated. Janesville v. Garthwaite, 83 Wis. 2d 866, 266 N.W.2d 418 (1978). This residual police power permits the city to target the manner of vehicle operation rather than equipment specifications. Stated another way:

[A] city may adopt and enforce a general noise ordinance that in some cases may apply to noise produced by a motor vehicle muffler. However, cities may not adopt or enforce a traffic ordinance that regulates mufflers or exhaust systems in a way that exceeds or conflicts with Wis. Stat. § 347.39. The Wisconsin Supreme Court addressed a similar interaction of local ordinances and state traffic laws related to squealing tires in Janesville v. Garthwaite.

In order to allow cities to adopt and enforce a traffic ordinance specifically regulating muffler noise, a statute could be created expressly authorizing them to do so. WLRB memo.

The WLRB memo is an accurate summary of relevant Wisconsin law; however it does not support a conclusion that decibel level noise ordinance could be enforced against an otherwise lawful muffler. In fact, the WLRB memo recognizes that a statute created would need to be created that expressly authorizes a city to do so. Absent statutory changes allowing more local regulation of vehicular noise, Appleton should focus any noise-reduction efforts on conduct-based ordinances that regulate how vehicles are driven, rather than unlawful strict decibel level standards that would conflict with § 347.39. Appleton already has properly drafted conduct-based ordinances that withstand preemption challenges and provide a lawful mechanism for addressing vehicular noise complaints.

Charles E. Sepers

From: Martyn Smith
Sent: Monday, June 8, 2026 11:53 AM
To: Jake Woodford; Polly Olson; Charles E. Sepers
Subject: Further Help with Noise Enforcement
Attachments: Snodgrass_excessivenoise (2).pdf; Screenshot 2026-06-08 at 11.33.17 AM.png

Hello Mayor Woodford, Chief Olson, and Director Sepers,

This past March I sent to Mayor Woodford a document from the Wisconsin Legislative Reference Bureau, responding to questions from Lee Snodgrass about noise enforcement at the city level. I saw the importance of this document for the questions we are facing here in Appleton. I would like to make sure this gets a good look and that its implications are understood. This document states that enforcement of noise is possible for cities so long as these do not cross over into the specific rules for mufflers. This opens up the possibility of giving citations purely for noise. In other words, if a vehicle exceeds the noise limits, it can be cited purely for that fact notwithstanding any specific issues related to mufflers. This is a point I have long asked about. I am attaching a sample from the city ordinances of Greenville, North Carolina (pop ~95k) to show how this has played out in another location. You can see that they are citing for noise irrespective of the muffler violations, and they make that clear in the ordinance. This path is certainly open for us. In addition, this would open up the possibility of remote ticketing for noise, something that the mayor has indicated would be of interest. According to the opinion given by the WLRB (and expanded upon with questions) there would be nothing prohibiting Appleton from such automatic noise citations. For now what I would like to do is make it clear that we could craft ordinance that allowed for ticketing purely on noise, and I would like to proceed with something that resembles the language in the Greenville, North Carolina ordinance. Please let me know if we can move forward on adding another tool for officers.

Thanks,
Martyn



WISCONSIN LEGISLATIVE REFERENCE BUREAU

MEMORANDUM

TO: Representative Lee Snodgrass
FROM: Eric Mueller, assistant chief counsel
Madeline Kasper, managing analyst
DATE: December 8, 2025
SUBJECT: City citations for excessive noise from motor vehicle mufflers

You asked whether state law prevents cities from issuing citations for excessive noise from motor vehicle mufflers, and what statutory changes would be required to allow cities to issue such citations.

Wisconsin cities operate under “home rule” authority, which grants them broad powers to regulate local affairs as long as their ordinances and actions do not conflict with state law.¹ This constitutional authority allows cities to regulate in most areas unless explicitly barred by the state. There is nothing under state law that prohibits or preempts cities from adopting general noise-nuisance ordinances. As such, most Wisconsin cities have such ordinances and enforce them through citations.

With regard to traffic ordinances, the statutes do provide specific limitations on cities. Generally, no governing body of a Wisconsin county or municipality may enact a traffic ordinance unless the ordinance strictly conforms to state traffic law or is expressly authorized by statute.² Wis. Stat. § [347.39](#) requires motor vehicles to be “equipped with an adequate muffler in constant operation and properly maintained to prevent any excessive or unusual noise or annoying smoke.” This section further prohibits modifications to a muffler or exhaust system that include a cutout, bypass, or similar device or to amplify the noise emitted by the vehicle. Since there is no statutory provision expressly authorizing cities to regulate muffler equipment beyond these state requirements, cities may only adopt and enforce muffler equipment ordinances in conformity with Wis. Stat. § [347.39](#).

¹ See Wis. Const. art. XI, § [3\(1\)](#) and Wis. Stat. § [62.11\(5\)](#). For more information on home rule, see this [brief](#) written by the Wisconsin Legislative Council.

² Together, Wis. Stat. §§ [349.03](#) and [349.06](#) create uniform traffic laws in Wisconsin. Under Wis. Stat. § [349.03](#), no local authority may enact or enforce any traffic regulations unless those regulations are consistent with Wis. Stat. chs. 341 through 350. Likewise, Wis. Stat. § [349.06](#) permits local authority to adopt traffic regulations in strict conformity with state law.

In short, a city may adopt and enforce a general noise ordinance that in some cases may apply to noise produced by a motor vehicle muffler. However, cities may not adopt or enforce a traffic ordinance that regulates mufflers or exhaust systems in a way that exceeds or conflicts with Wis. Stat. § [347.39](#). The Wisconsin Supreme Court addressed a similar interaction of local ordinances and state traffic laws related to squealing tires in [Janesville v. Garthwaite](#).³

In order to allow cities to adopt and enforce a traffic ordinance specifically regulating muffler noise, a statute could be created expressly authorizing them to do so. As a related example, Wis. Stat. § [66.0411](#) expressly permits cities and other municipalities to adopt and enforce ordinances prohibiting excessive noise from sound-producing devices on vehicles (such as radios) in certain circumstances, including authority to impound such devices in certain circumstances.

Please let us know if you have any additional questions.

³ 83 Wis. 2d 866, 266 N.W.2d 418 (1978).



SEC. 12-5-9 MOTOR VEHICLE NOISE.

(A) It shall be unlawful for any person to drive, operate, move or permit to be driven, operated or moved a motor vehicle or combination of vehicles at any time in such a manner that the sound level of the vehicle exceeds the levels set forth for that category of vehicles as shown below:

TABLE 3: MAXIMUM MOTOR VEHICLE SOUND LEVEL IN dB(A)

<i>Vehicle Type</i>	<i>Speed Limit 35 mph or Less</i>	<i>Speed Limit 35 mph or More</i>	<i>Vehicle Stationary</i>
Motor vehicle with a gross vehicle weight rating (GVWR) of less than 10,000 pounds	81	85	83
Motor vehicle with a GVWR of more than 10,000 pounds	89	94	91
Motorcycle	81	85	83
Any other motor vehicle or any combination of vehicles towed by any motor vehicle	76	80	78

(B) Sound levels are to be measured at a distance of 25 feet from the nearest lane(s) being monitored and at a height of at least four feet above the immediate surrounding surface.

(C) This section shall apply to the total noise from a vehicle and shall not be construed as limiting or precluding the enforcement of any other provisions of this chapter relating to motor vehicle mufflers or noise control.

(D) Traffic, aircraft and other transportation noise sources and other background noises shall not be considered in taking measurements under this section.

(E) *Penalties.* A violation of this section may subject the violator to any or all of the following penalties:

(1) *Criminal.* Any person violating any provision of this section shall be guilty of a Class 3 misdemeanor pursuant to G.S. 14-4 and G.S. 160A-175 and shall pay a criminal penalty of not less than \$100 and not more than \$500.

(2) *Civil.*

(a) A violation of any of the provisions of this section shall subject the violator to a civil penalty by way of a civil ticket in an amount as follows:

1. *First violation.* A violation of this section shall subject the violator to a civil penalty of \$100.
2. *Second violation within 365 days of the first violation.* A second violation of this section by the violator within 365 days from herein defined first violation shall subject the violator to a civil penalty of \$250.
3. *Third and subsequent violations within 365 days of the first violation.* A third violation and any subsequent violations of this section by the violator within 365 days from herein defined first violation shall subject the violator to a civil penalty of \$500 per violation.

(b) *Appeals; payment of civil penalty; delinquency charge.* Unless appealed in accordance with Part II, Title 1, Chapter 1, Section 20 of the City Code, a civil penalty assessed for a violation of any provision of this section must be paid to and received by the revenue division of the city's Financial Services Department within five business days from the date of issuance. If the civil penalty is not timely paid to and received by the revenue division of the city's Financial Services Department within five business days from the date of issuance, the violator will be assessed an delinquency charge of an additional \$50 for each 72-hour period thereafter upon nonpayment until paid in full.



CITY OF APPLETON

PUBLIC HEALTH DEPARTMENT & POLICE DEPARTMENT | JOINT REPORT

Noise Complaint Enforcement Analysis: 2026 Statistical Brief

YTD Comparison | January 1 – May 31 | 2022 through 2026 | Completed June 2026

EXECUTIVE SUMMARY

In the first five months of 2026, Appleton officers issued **306 enforcement actions** for noise violations — **43 percent more** than the average of 214 over the previous four years. This increase happened while the number of noise complaints stayed flat. Officers are not responding to more calls. They are responding more assertively to the same volume of calls while creating opportunities to be proactive to initiate more stops not associated with complaints at all. This report examines where, when, and how that shift occurred, and what it means for public health and neighborhood quality of life.

LOGIC MODEL: NOISE ENFORCEMENT THEORY OF CHANGE

This logic model explains why noise enforcement actions rose sharply in 2026 even though noise complaints stayed the same. It shows how specific policy and practice changes, such as the College Avenue lane reconfiguration, ordinance changes that gave more discretion to officers in the field, and flexible K9 officer scheduling led officers to take more direct and timely action. Officers use their training in state traffic law and city code to tell the difference between lawful noise, such as legal vehicle exhaust, and unlawful driver behavior. Acting on that difference right away, at the moment it happens, is what is most likely to change driver behavior over time.

Complaint data may lag behind what is actually happening on the street. A driver who changes behavior because of an enforcement action will not show up right away as a drop in complaints. This gap should be kept in mind when reading complaint trends over the next one to two years.

It is also important to note that the districts analyzed in this report correspond to the three law enforcement districts within the City: Northern, Southern, and Downtown. These districts correspond with APD's command and control structure.



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Inputs	Activities	Outputs	Short-Term Outcomes	Long-Term Outcomes / Impact
<ul style="list-style-type: none"> - Revised 2025 noise ordinance giving officers subjective judgment authority - Revised towing ordinance for reckless driving - College Avenue lane reconfiguration - Flexible K9 officer schedule - Internal officer training on enforcement tools - \$215,000 DOT traffic grant funding - Officer expertise in state and municipal law 	<ul style="list-style-type: none"> - Officers patrol proactively, not only responding to calls - Officers apply new ordinance tools and use judgment in the moment - Officers spot and isolate disruptive drivers more easily in the simplified single-lane corridor - Officers use towing authority for reckless driving cases - Leadership reinforces consistent enforcement expectations - Grant-funded traffic stops overlap with noise enforcement 	<ul style="list-style-type: none"> - 306 enforcement actions in 2026, 43% above the four-year average - Enforcement rate of 1.52 actions per complaint, 44% above average - 171 warnings and 135 citations issued - Confirmed increases in Downtown (+48%) and Northern (+58%) Districts - More proactive stops not tied to a phoned-in complaint 	<ul style="list-style-type: none"> - Drivers experience an immediate consequence at the moment of the behavior, the point at which behavior change is most likely - Unlawful driving behavior, such as reckless acceleration or illegal exhaust modification, is separated from lawful vehicle noise - A graduated response, warning first, encourages voluntary compliance - Disruptive driving becomes more visible and easier to identify on College Avenue 	<ul style="list-style-type: none"> - Fewer unlawful noise-generating driving incidents over time in targeted corridors and districts - Improved sleep, mental health, and quality of life for residents, especially in Downtown and Northern Districts - More even, complaint-proportional enforcement across all three districts - Complaint counts may not fall right away, and may lag behind real improvements in driver behavior - A sustainable, data-informed enforcement practice citywide



CITY OF APPLETON

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Noise Complaint Enforcement Analysis: 2026 Statistical Brief

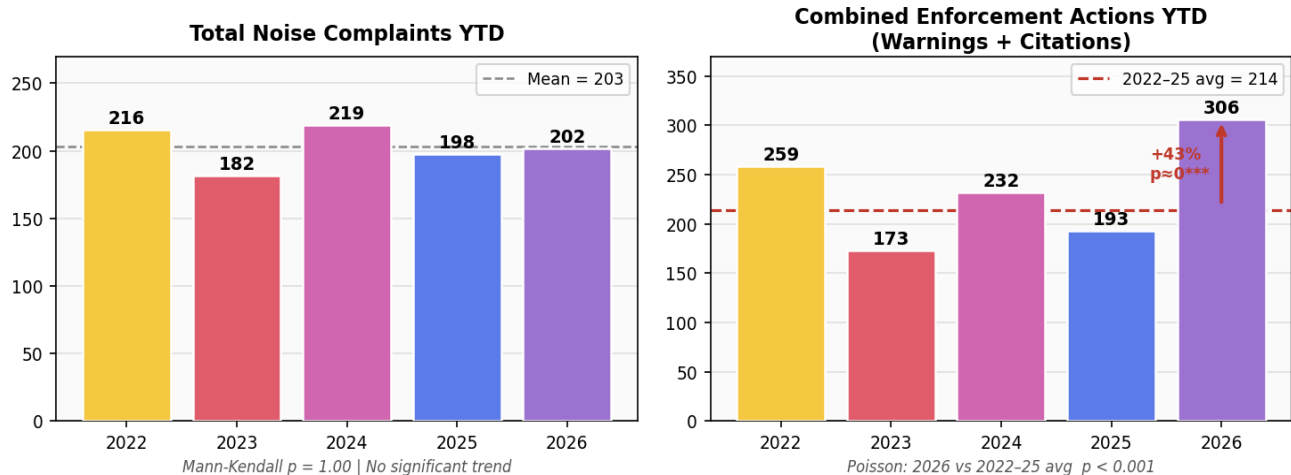
YTD Comparison | January 1 – May 31 | 2022 through 2026 | Completed June 2026

IMPORTANT CONTEXT AND ASSUMPTIONS

- Under Wisconsin law, noise from an unmodified vehicle exhaust is legal at any level and cannot be regulated by local ordinance. This model assumes enforcement targets unlawful behavior, such as illegal exhaust modification or reckless driving, not lawful vehicle noise.
- Trained officers can observe driver behavior in real time and apply their knowledge of state traffic law and municipal code. Noise complaint data alone cannot make this same distinction.
- There is likely a delay between when an enforcement action changes driver behavior and when that change shows up as fewer complaints in the data. Short-term complaint totals should be interpreted with this lag in mind.

1. COMPLAINT VOLUME REMAINED STABLE

Noise complaint totals have been consistent for five years. Each year between 2022 and 2026, residents filed between 182 and 216 noise complaints during the January through May period. The 2026 total of 202 sits right in the middle of that range. There is no upward trend, no downward trend — just steady year-to-year variation around a stable baseline.



The chart above tells the central story of this report: the blue bars (complaints) remain flat while the orange bars (enforcement actions) climb sharply in 2026. This gap is the key finding. **Complaint volume alone cannot explain the enforcement increase.** Something changed in how officers applied enforcement, not in how often residents called.



CITY OF APPLETON

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Noise Complaint Enforcement Analysis: 2026 Statistical Brief

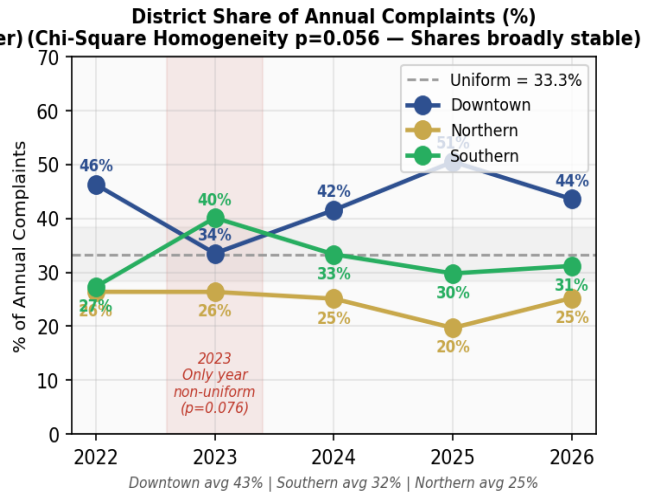
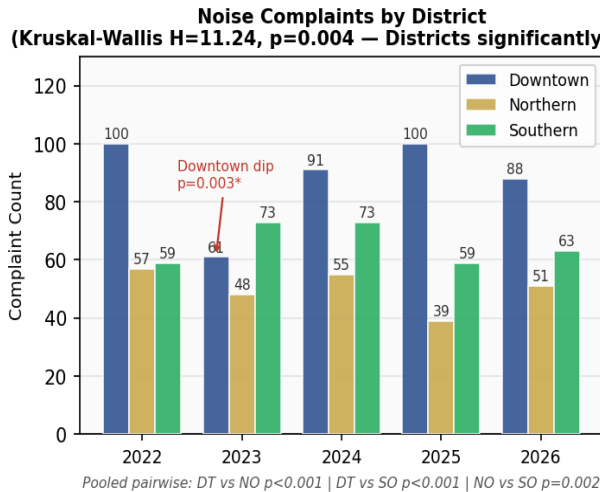
YTD Comparison | January 1 – May 31 | 2022 through 2026 | Completed June 2026

WHY THIS MATTERS

- A rise in enforcement that tracks a rise in complaints would indicate officers are simply keeping pace with demand. The stability of complaints in 2026 rules that explanation out entirely. The increase in enforcement reflects a change in officer behavior or departmental practice, not a change in the noise environment.
- The 2023 and 2024 complaint counts were the lowest in the five-year window, yet enforcement actions in 2026 are the highest on record. Complaint volume and enforcement levels have decoupled.

2. WHERE DO COMPLAINTS COME FROM?

Noise complaints are not spread evenly across the city. Downtown consistently draws the most complaints, followed by the Southern District and then the Northern District. This three-tier pattern has been stable for all five years studied, with one notable exception in 2023.



District	Share of All Complaints	Five-Year Pattern
Downtown	43% of all complaints	Highest in four of five years; avg. 88 complaints per year
Southern	32% of all complaints	Middle tier consistently; avg. 65 complaints per year
Northern	25% of all complaints	Lowest in all five years; avg. 50 complaints per year



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Noise Complaint Enforcement Analysis: 2026 Statistical Brief

YTD Comparison | January 1 – May 31 | 2022 through 2026 | Completed June 2026

The size of the gaps between districts is not a coincidence. Analysis confirms all three pairwise differences—Downtown vs. Northern, Downtown vs. Southern, and Northern vs. Southern—are too large to be explained by chance alone. Downtown generates roughly **76% more complaints than Northern** and **35% more than Southern** when the full five years are pooled together. These are enduring structural differences in noise complaint patterns across Appleton's three policing districts.

Are Actions Proportional to Where Complaints Come From?

A separate and important question is whether enforcement is distributed in proportion to where complaints originate. If Downtown generates 43% of complaints, it should receive roughly 43% of enforcement actions if officers respond equally across the city. Analysis shows this proportionality has **not held consistently**.

Downtown has consistently received **more enforcement than its complaint share would predict**, while Southern District has trended toward receiving **less**. In 2026, Downtown's enforcement rate per complaint (1.83) was 21% above the city average, while Southern's (1.18) was 22% below. This pattern was confirmed in three of the five years studied.

The 2023 Exception: Downtown's Unusually Quiet Year

The right panel of the chart above shows how each district's share of complaints has changed over time. In most years, the three districts hold steady at roughly their long-run averages. 2023 stands out as the one year where Downtown's share dropped sharply to just 33% of complaints, from its typical 43%. In that year, Downtown received only 61 complaints, compared to its four-year average of about 95.

This drop was large enough that the three districts were statistically close to equal in 2023, the only year this occurred. Analysis confirms the Downtown dip in 2023 is a genuine anomaly. This downturn is almost certainly attributed with the College Avenue lane reconfiguration. The familiar complaint hierarchy returned in 2024 and 2025.

KEY TAKEAWAY

- Downtown, Southern, and Northern Districts have distinct and stable complaint volumes. Understanding which parts of the city generate the most noise calls is important context for evaluating where enforcement resources are deployed.
- Because districts differ significantly in complaint volume, direct comparisons of enforcement counts across districts must account for this underlying difference. A district with twice the complaints would be expected to see roughly twice the enforcement actions if response rates were equal.



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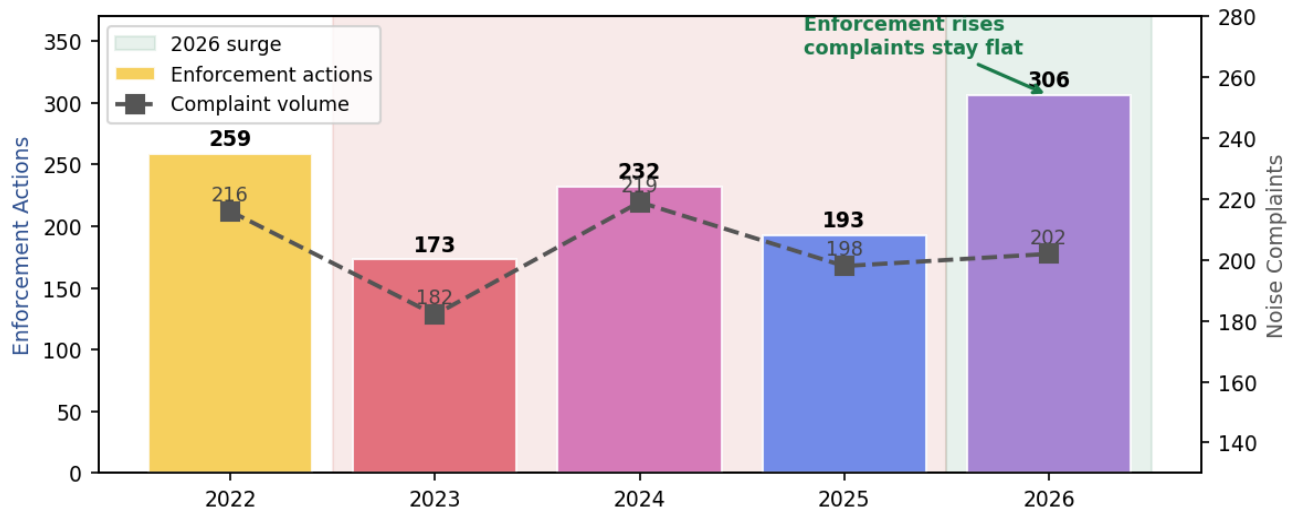
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3. ENFORCEMENT ACTIONS INCREASED SHARPLY IN 2026

Combining warnings and citations gives a complete picture of enforcement activity. In 2026, officers issued **306 total actions**, the highest count in the five-year dataset. This exceeds even 2022 (259 actions), which was previously the highest year. The four-year average before 2026 was 214 actions, meaning 2026 came in **43% above that average**.

Enforcement Actions vs. Complaint Volume — 5-Year Overview



The chart above shows how 2026 compares to the full five-year history. Two years (2023 and 2025) were confirmed enforcement troughs, with officer actions running 25 to 33 percent below the 2022 baseline. Those low-enforcement years make the 2026 surge appear even larger by contrast. Part of what we see in 2026 may be a recovery from those suppressed years; even measured against 2022, however, enforcement in 2026 is meaningfully elevated.

Metric	Number	What It Means
2026 total actions	306	The highest single-year total in the five-year window
Prior four-year average	214	The baseline for comparison: 2022 through 2025 combined
Percent above average	+43%	The size of the 2026 increase over the prior average
2023 enforcement (trough)	173	The lowest year on record — context for the 2026 rebound



CITY OF APPLETON

PUBLIC HEALTH DEPARTMENT & POLICE DEPARTMENT | JOINT REPORT

Noise Complaint Enforcement Analysis: 2026 Statistical Brief

YTD Comparison | January 1 – May 31 | 2022 through 2026 | Completed June 2026

WHAT THE NUMBERS SHOW

- The 2026 increase is too large to be explained by year-to-year variation. A difference of this size, confirmed against a stable complaint baseline, points to a genuine change in enforcement practice.

FACTORS CONTRIBUTING TO INCREASED ENFORCEMENT

- **K9 officer scheduling.** Effective in 2026, four K9 officers were moved from scheduled patrol shifts to a flexible schedule. This increased their availability for self-initiated enforcement activity — including noise and traffic enforcement — and reduced the need for overtime. These officers patrol without taking calls in the normal rotation, allowing them to focus on proactive enforcement.
- **Internal expectations and education.** The department invested significant time in internal messaging around expectations for noise and traffic enforcement. Officers were educated on all available enforcement tools for addressing unlawful driver behavior. This education push was closely tied to a revision of the noise ordinance in 2025, which gave officers an opportunity to reset their approach to enforcement.
- **Noise ordinance update.** In 2025, the City adopted a new noise ordinance that added greater tools for officers to enforce compliance by allowing subjective measurement, relying on officer training rather than objective noise readings to enforce compliance. Additionally, the new ordinance was modernized and made clarifications by removing confusing language, which also benefited compliance action.
- **Towing ordinance update.** A change to the towing ordinance related to reckless driving added a new enforcement tool. Officers were educated on this change as part of the broader effort to ensure awareness of all options available when responding to noise and traffic-related calls.
- **Traffic grant funding.** The department carries \$215,000 in special revenue grant funding from the Department of Transportation for OWI, seatbelt, and speed enforcement. While these grants are not new to 2026 and are not directly connected to noise violations, they support additional traffic enforcement activity that overlaps with the department's noise enforcement strategy. Some of this grant activity was directed toward the Downtown area.
- **College Ave lane reconfiguration.** The lane reconfiguration helped reduce noise by limiting the ability of drivers to weave, accelerate aggressively, or "cruise" through the corridor in multiple lanes. This structural change also made disruptive vehicles more conspicuous to officers and allowed for easier identification and isolation of those drivers within the simplified, single-lane flow.



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PUBLIC HEALTH DEPARTMENT & POLICE DEPARTMENT | JOINT REPORT

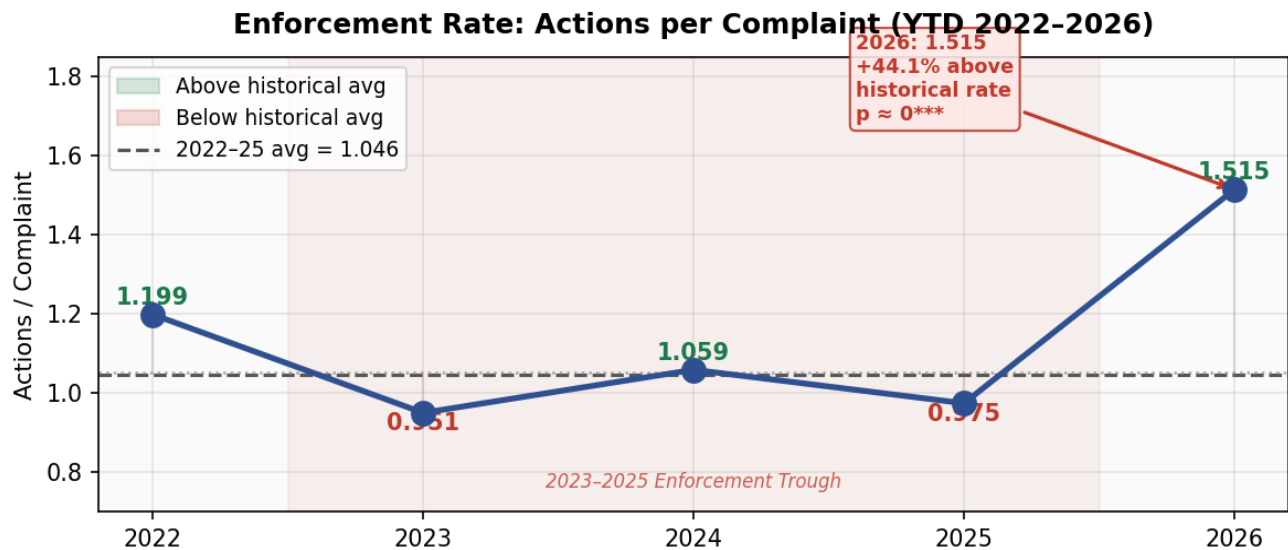
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4. HOW MANY ACTIONS PER COMPLAINT?

Dividing total enforcement actions by the number of complaints received gives the **enforcement rate**, a measure that separates officers from complaint volume. If the enforcement rate goes up, it means officers are issuing more actions for the same volume of calls they are responding to.

In 2026, the enforcement rate was **1.52 actions per complaint**, the highest in five years. For context, a rate above 1.0 means officers are issuing more than one action per complaint on average. This happens when a single incident results in both a warning and a citation, or when multiple people at one location each receive a separate action.



The 2023 and 2024 enforcement rates were both well below 1.0, meaning officers were responding to many complaints without issuing a formal warning or citation. The 2026 rate of 1.52 is **44% higher than the pooled rate** across the prior four years (approximately 1.05). This confirms the 2026 increase is driven by a change in how actively officers are enforcing noise ordinances, not by a change in the number of calls they are answering.

KEY TAKEAWAY

- The enforcement rate is the clearest measure of whether officer behavior changed. Because it divides actions by complaints, it removes any effect of complaint volume entirely. The 44% increase in the 2026 enforcement rate, against a flat complaint baseline, confirms this is a behavioral shift.
- From a public health perspective, this matters because enforcement actions represent direct interventions that can deter future noise activity and improve neighborhood sleep quality, access to mental health services, and resident satisfaction.



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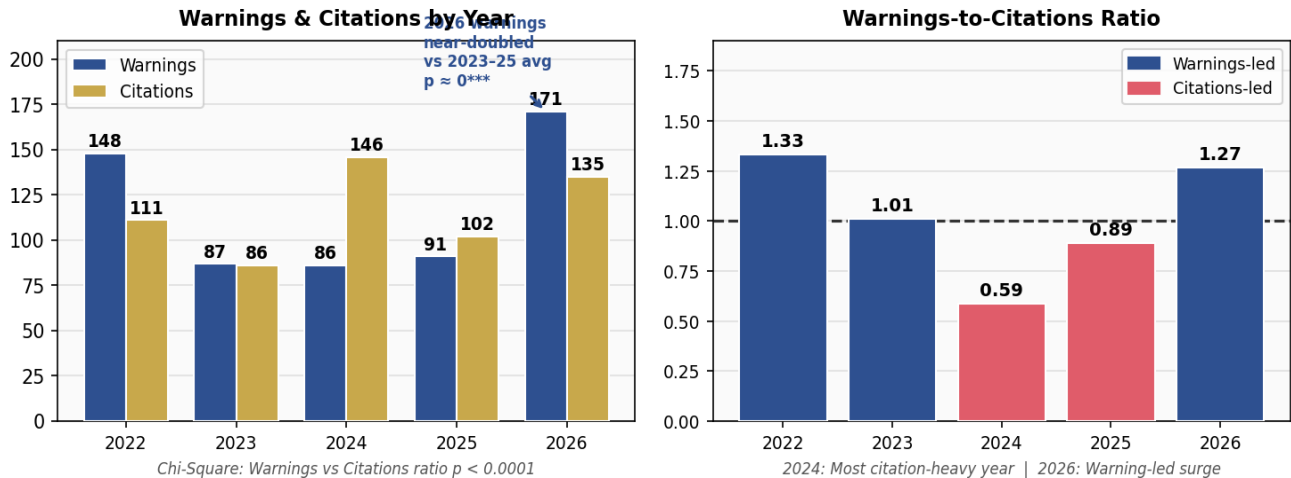
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5. A SHIFT TOWARD WARNINGS

Enforcement actions are not all the same. Warnings give residents a chance to correct behavior without formal penalty. Citations carry fines and create an official record. Looking at both separately reveals an important detail about the nature of the 2026 surge.

The 2026 increase in noise enforcement action was **led by warnings, not citations**. Officers issued 171 warnings in 2026, nearly double the average of 88 per year from 2023 to 2025. Citations rose more modestly, from a trough-period average of roughly 111 per year to 135 in 2026.



The balance between warnings and citations has shifted considerably over five years. In 2024, the department was more citation-heavy than any prior year, issuing roughly one warning for every two citations. In 2026, that ratio more than inverted: officers issued **approximately 1.27 warnings for every citation**. This is a significant policy-relevant change in how enforcement is being applied. Warnings also serve as a critical principle in community policing.

Metric	Number	What It Means
2026 warnings issued	171	Nearly double the 2023–2025 average of 88 per year
2026 citations issued	135	Moderately above the 2023–2025 average of 111 per year
2026 warnings-to-citations	1.27	More than one warning for every citation — a five-year high
2024 warnings-to-citations	0.59	The citation-heavy year — the opposite of 2026’s pattern



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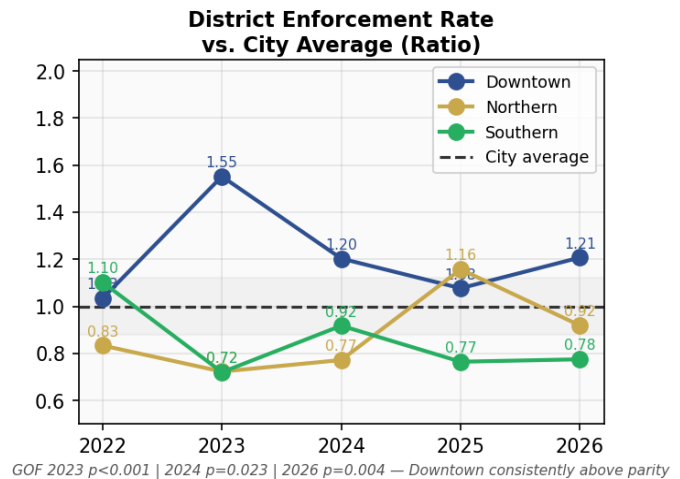
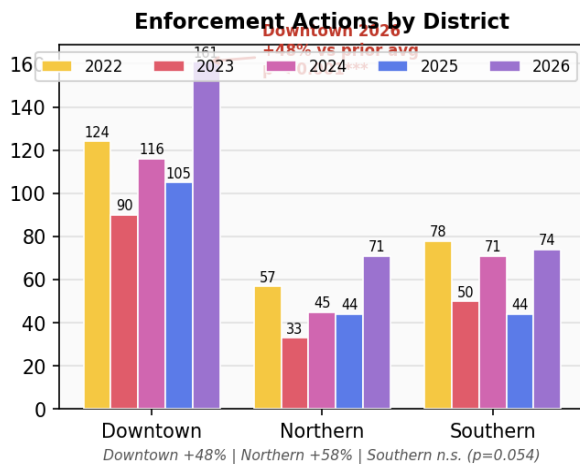
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WHAT THIS SHIFT COULD MEAN

- The move toward warnings rather than citations could reflect a deliberate graduated response strategy: officers issue a warning before escalating to a citation. This approach may generate fewer formal penalties while still deterring noise activity.
- From a public health standpoint, warnings are a lower-barrier intervention. A high warning rate means officers are engaging more proactively per training and discretion. If warnings are effective at changing behavior, residents in affected neighborhoods may benefit even when citations are not issued.

6. WHERE DID ENFORCEMENT INCREASE?

The citywide enforcement increase was not distributed evenly across all three law enforcement districts. Looking at each district separately reveals a concentrated pattern: two of three districts drove the surge, while the third saw a smaller and less certain increase.





CITY OF APPLETON

PUBLIC HEALTH DEPARTMENT & POLICE DEPARTMENT | JOINT REPORT

Noise Complaint Enforcement Analysis: 2026 Statistical Brief

YTD Comparison | January 1 – May 31 | 2022 through 2026 | Completed June 2026

Metric	Number	What It Means
Downtown District 2026	161 actions	48% above its 2022–2025 average of 109 — confirmed increase
Northern District 2026	71 actions	58% above its 2022–2025 average of 45 — confirmed increase
Southern District 2026	74 actions	22% above its 2022–2025 average of 61 — not conclusive

Downtown and Northern Districts each saw enforcement increases large enough to rule out chance. Southern District’s 22% increase, while notable, falls just short of statistical certainty and could be due to chance.

Are Actions Proportional to Where Complaints Come From?

A separate and important question is whether enforcement is distributed in proportion to where complaints originate. If Downtown generates 43% of complaints, it should receive roughly 43% of enforcement actions if officers respond equally across the city. Analysis shows this proportionality has **not held consistently**.

Downtown has consistently received **more enforcement than its complaint share would predict**, while Southern District has trended toward receiving **less**. In 2026, Downtown’s enforcement rate per complaint (1.83) was 21% above the city average, while Southern’s (1.18) was 22% below. This pattern was confirmed in three of the five years studied.

KEY TAKEAWAY

- The geographic picture suggests the 2026 enforcement surge was primarily a Downtown and Northern District phenomenon. Downtown, already the highest-complaint district, received both the largest absolute increase and the highest enforcement rate per complaint.
- The persistent gap between Downtown’s enforcement rate and Southern’s rate warrants attention. Whether this reflects differences in the severity or complexity of incidents, officer deployment patterns, or other factors is a question the aggregate data cannot fully answer. Incident-level review could clarify this.
- From a public health equity perspective, the question of whether residents in all three districts receive proportionally similar enforcement responses is worth monitoring over time.



CITY OF APPLETON

PUBLIC HEALTH DEPARTMENT & POLICE DEPARTMENT | JOINT REPORT

Noise Complaint Enforcement Analysis: 2026 Statistical Brief

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CONCLUSIONS

This report examined five years of noise complaint and enforcement data from Appleton. The five key conclusions, supported by statistical analysis, are:

- 1. Noise complaints are stable.** The number of noise complaints filed each year has not changed meaningfully from 2022 to 2026. The 2026 enforcement surge cannot be explained by an increase in calls.
- 2. Complaints are unevenly distributed across the city.** Downtown attracts 43% of all complaints, Southern 32%, and Northern 25%. This three-tier hierarchy is consistent and confirmed across the full five-year period. 2023 was the sole exception, driven by an unexplained dip in Downtown complaints.
- 3. Enforcement actions in 2026 reached a five-year high.** At 306 combined actions, 2026 exceeded every prior year by a wide margin. Measured against the prior four-year average, this represents a 43% increase. The enforcement rate per complaint — a measure that removes the effect of complaint volume — rose by 44%.
- 4. The surge was led by warnings, not citations.** Officers issued roughly twice as many warnings in 2026 as in the three preceding years.
- 5. The increase was concentrated in Downtown and Northern Districts.** Both districts saw enforcement rise well above their historical averages, with confirmed statistical significance. Southern District showed a smaller increase that did not reach statistical certainty. Downtown continued a multi-year pattern of receiving enforcement at a higher rate than its complaint share alone would predict.
- 6. Citations are likely to be much higher in 2026.** In 2025, APD issued a total of 216 noise citations for the entire year, or about 18 per month. In 2026, the YTD totals show a rate of 27 citations per month. The current rate will produce an increase of about 50% of citations over the 2025 totals.
- 7. Strategy effectiveness.** Code enforcement action at the point of which unlawful behavior is observed serves as the most effective strategy for changing driver behavior. The theory change predicts that with increased enforcement actions, the greater the change to driver behavior.

This brief was prepared using year-to-date data (January 1 – May 31) for each year from 2022 through 2026. All figures compare equivalent observation windows of 151 days. Statistical analysis was performed to confirm which observed differences are genuine rather than the result of random year-to-year variation. Methods included trend tests, rate-ratio tests, chi-square tests, and non-parametric comparisons with corrections applied for multiple simultaneous comparisons. No individual incident-level data was used; all analysis is based on aggregate counts from APD data.