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Smart Horn Systems in Connected Vehicles: A Pathway to Reducing Urban Noise Pollution

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Connected Vehicle (CV) technology is transforming the landscape of modern transportation by enabling seamless communication between vehicles (V2V), infrastructure (V2I), and pedestrians (V2P). By leveraging wireless communication standards such as Dedicated Short-Range Communication (DSRC) and Cellular Vehicle-to-Everything (C-V2X), connected vehicles aim to enhance road safety, traffic efficiency, and environmental sustainability. However, one often-overlooked issue in urban environments—vehicular noise pollution, particularly from excessive horn usage—remains largely unaddressed by current CV systems. This research introduces a novel feature within the domain of V2V communication: an Interior-Only Audible Horn System. The proposed system enables vehicles within a defined vicinity to transmit horn signals wirelessly to one another, with the alert sound being played only inside the cabin of the target vehicle. As a result, pedestrians and nearby non-target vehicles are not disturbed by unnecessary horn noise, significantly reducing overall urban noise pollution. The system architecture incorporates onboard vehicle sensors, digital horn activation mechanisms, and secure short-range communication protocols. The horn signal is encapsulated as a digital alert packet, transmitted over the CV network, and decoded only by vehicles within the immediate alert zone. The paper also presents simulations and a prototype implementation demonstrating the system's effectiveness in both reducing ambient horn noise and maintaining driver awareness and safety. This innovation represents a step forward in creating smarter, quieter, and more sustainable urban mobility ecosystems by combining environmental sensitivity with the growing potential of connected vehicle networks.

Whenever we are walking on a footpath besides the roads, especially in the metropolitan cities, we hear annoying noise from the horns of cars, bikes, etc. This noise is very irritating, discomforting and Noise-Guard is a new age automobile horn system designed specifically to reduce noise pollution caused by the automobiles. The noise-guard circuit has to be installed in all automobiles in order to make it successful for noise pollution reduction. Through this system, any two or more nearby automobiles are connected to each other through radio communication system, just like the radio channels we tune in our cars to listen to songs. The traditional horn systems are placed at the center of a steering of an automobile. The same horn button is replaced by the button of the Noise-Guard. When a driver in one car presses "Noise-Guard" on his steering, a horn sound will be played inside the interior of each car that is connected to it. Every Noise Guard must be operating at the same radio frequency in order to receive alert from any nearby automobile. This way, we can reduce the noise pollution by about 30 to 50 percent. This system However, fancy this may seem, there are some loopholes in this system. What about the people who are crossing the road or just standing on the road? What about the bikes, bicycles, animals on the road? How can we alert such elements of the road traffic system? Therefore, while building such systems, we need to take care of these elements also. For this reason, "Noise-Guard" does not replace the traditional horn system; instead it adds an extra feature to the old system to make it futuristic.

Keywords: noise pollution, connected vehicle, vehicle infrastructure

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1. Introduction

Connected Vehicle Technology is revolutionizing the transportation sector by enabling vehicles to communicate with each other, with infrastructure, and with external networks (like the cloud and the internet). This is often referred to as V2X communication (Vehicle-to-Everything). Let us dive deep into the most amazing and impactful features of this technology. There are many features-cum-advantages of connected vehicle technology:

1. Vehicle-to-Vehicle (V2V) Communication which enables real-time communication between vehicles and vehicles can share information about speed, heading, braking, and location. It reduces accidents by enabling automatic braking or steering to avoid collisions.
2. Vehicle-to-Infrastructure (V2I) Communication through which Vehicles communicate with road infrastructure (traffic lights, signs, toll booths) and helps vehicles know about upcoming traffic signals, road work, or hazards. It also optimizes traffic flow, reduces congestion, and improves fuel efficiency.
3. Vehicle-to-Network (V2N) Integration system connects vehicles to cloud services and cellular networks (like 5G) and therefore enables access to real-time data such as weather, navigation, and entertainment. This feature enhances in-car experience and supports remote diagnostics and updates.
4. Vehicle-to-Pedestrian (V2P) Alerts which detects and communicates with mobile devices carried by pedestrians and cyclists. It also warns drivers or autonomous systems of nearby people, even around corners and hence dramatically increases pedestrian safety, especially in urban areas.
5. Remote Vehicle Monitoring and Control Feature allows owners and service centers to monitor and control vehicles remotely including starting the engine, checking diagnostics, setting geo-fences thereby enhancing convenience, safety, and proactive maintenance.
6. Intelligent Navigation and Route Optimization feature utilizes real-time data for dynamic route planning. Through this feature, an automobile system integrates with traffic, weather, and construction updates. There are several benefits of this feature such as it saves time, reduces emissions, and improves driver satisfaction.
7. Collision Avoidance and Emergency Alert system alerts drivers about imminent threats like red-light runners, blind spot vehicles, etc. It works in conjunction with sensors and V2X communication and can prevent multi-vehicle pileups and improve emergency response.
8. Cybersecurity Integration includes embedded encryption and intrusion detection systems and protects data communication between vehicles and systems. It ensures privacy, prevents hacking, and builds trust in automation.
9. Over-the-Air (OTA) Updates enables software updates delivered wirelessly. It also includes firmware upgrades, bug fixes, and new feature rollouts and thereby keeping vehicle systems up-to-date without dealer visits.
10. Data Analytics and Fleet Management ensures real-time data aggregation for performance and logistics. It is used in commercial fleets to track fuel use, driver behavior, and routes. It increases operational efficiency and reduces costs.
11. Integration with Smart Cities feature is a part of a broader ecosystem involving IoT and AI through which vehicles contribute data to city systems for planning and real-time management, thereby supporting sustainable urban development and environmental monitoring.
12. Autonomous Driving Support feature is a foundation for fully autonomous driving and provides a constant stream of environmental and traffic data to AI systems and enables safe and reliable self-driving capabilities.

These features are listed in the following table:

Feature	Description	Benefits
Vehicle-to-Vehicle (V2V) Communication	Enables real-time communication between vehicles to share speed, location, and braking info.	Reduces collisions and enhances road safety.
Vehicle-to-Infrastructure (V2I) Communication	Allows communication with traffic lights, signs, and road conditions.	Improves traffic flow, reduces congestion and emissions.
Vehicle-to-Network (V2N) Integration	Connects vehicles to cloud and internet via 5G or LTE.	Enables real-time navigation, software updates, and infotainment.
Vehicle-to-Pedestrian (V2P) Alerts	Detects and communicates with mobile devices carried by pedestrians.	Enhances safety for pedestrians and cyclists.
Remote Vehicle Monitoring and Control	Allows remote diagnostics, engine start, or locking/unlocking via apps.	Provides convenience and enhances theft protection.

Intelligent Navigation and Route Optimization	Uses real-time data for dynamic and eco-friendly route planning.	Saves time, fuel, and reduces environmental impact.
Collision Avoidance and Emergency Alerts	Alerts drivers about possible collisions or dangers using sensors and V2X data.	Prevents accidents and improves emergency response time.
Cybersecurity Integration	Includes encryption and threat detection in vehicle systems.	Protects against hacking and ensures data privacy.
Over-the-Air (OTA) Updates	Wireless updates for software and firmware.	Eliminates need for dealer visits and keeps systems current.
Data Analytics and Fleet Management	Provides real-time insights for logistics and commercial fleet operations.	Improves efficiency and reduces maintenance costs.
Integration with Smart Cities	Shares vehicle data with urban infrastructure.	Aids in urban planning and traffic control.
Autonomous Driving Support	Provides continuous data feed for AI systems.	Enables safer and more reliable autonomous driving.

Table 1: Features and benefits of connected vehicle technology

Although these features are essential for any connected vehicle, there is one feature it must include to make it environment friendly, user-friendly and reduce pollution. This feature is "Noise Guard." This system enables horn systems between connected cars to integrate with each other and reduce noise pollution outside. People living in metropolitan areas have to suffer enormously due to various kinds of pollutions, such as air pollution, land pollution and the noise pollution. Among these three main types of pollutions, noise pollution is mainly caused by construction sites, marriage ceremonies, Rallies, Street March, Loudspeakers and unnecessary honking by automobile drivers. The system developed herein considers the noise pollution caused by unnecessary (and sometimes necessary) honking by automobile drivers. There are several areas in the metropolitan cities where one can find this problem; such as the areas where road construction is going on, the area with heavy traffic, the traffic signals, the markets, etc. In such areas, the automobile drivers and the bike riders unnecessarily keep on honking even though they know that they can not pass or overtake the proceeding automobile, may it be due to the red signal or due to heavy traffic. This creates noise pollution not only to the other automobiles in the vicinity but even severely to the pedestrians and nearby residents as they receive the loud sound directly.

Imagine yourself in a situation where you are standing/walking near a traffic signal or traffic area. If one stands there for 5-10 minutes, the loud sound of automobile horn becomes unbearable. The sound is very irritating, discomforting and may cause some health-related issues such as headache, panic attack, etc. Hence, the unnecessary honking by automobile drivers is a severe cause of noise pollution and a solution for this life-threatening problem is a need of the hour.

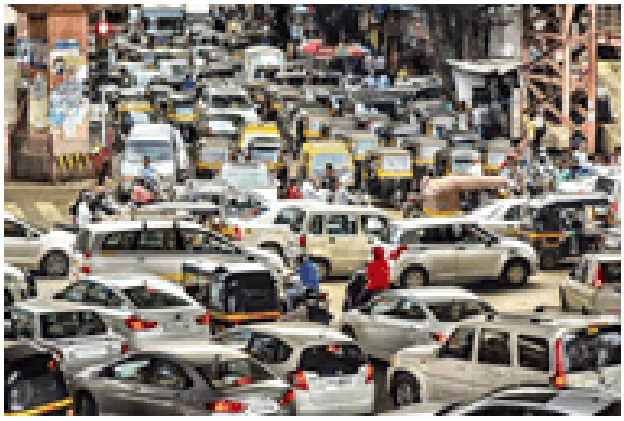


Figure1: Traffic in Mumbai

Figure 2: Traffic in Hyderabad

Figure 3: Traffic in Delhi

Ask yourself a question, "why do the automobile drivers honk at the first place?" Well, the answer to this question is simple and known to everyone. The main objective behind honking is to alert the proceeding automobiles either while overtaking them or to make them move out of the way if they are not moving due to some reason. Now ask yourself another question, "If it is just about the alert, can't we give this alert inside the interior of the automobile?" Well, the answer is "YES, WE CAN." The system presented herein makes this possible. The system is called as the "Noise-Guard" and it is similar to the traditional horn systems installed in the automobiles at the steering with only one difference that this system produces sound of the horn inside the interior of the automobile and thereby reduces noise pollution by at least 30 to 50 percent.

2. Literature Review

1. Connected Vehicle Technology and Vehicle-to-Vehicle (V2V) Communication

Connected Vehicle (CV) technology represents a transformative approach in modern transportation, enabling vehicles to communicate with each other (V2V), infrastructure (V2I), and pedestrians (V2P) to enhance safety, efficiency, and environmental sustainability. Utilizing wireless communication standards such as Dedicated Short-Range Communication (DSRC) and Cellular Vehicle-to-Everything (C-V2X), CVs facilitate real-time data exchange, allowing for proactive responses to traffic conditions, hazards, and other road events.

V2V communication, a subset of CV technology, allows vehicles to share information like speed, position, and heading, which is crucial for applications such as collision avoidance, cooperative adaptive cruise control, and traffic signal optimization. By integrating V2V capabilities, vehicles can coordinate actions, leading to smoother traffic flow and reduced congestion.

2. Noise Pollution from Vehicular Horns: A Growing Concern

Urban noise pollution has emerged as a significant public health issue, with vehicular horns being a notable contributor. Excessive honking, especially in densely populated areas, leads to increased stress levels, sleep disturbances, and even cardiovascular problems among residents.

Studies have shown that noise levels in urban intersections can reach alarming levels, primarily due to frequent horn usage.

For instance, a study conducted in Taiwan analysed horn usage at urban intersections and found a direct correlation between traffic volume and horn frequency. The research highlighted that unnecessary honking, often due to driver impatience or lack of awareness, significantly elevated ambient noise levels, adversely affecting the acoustic environment.

3. Innovations in Horn Systems to Mitigate Noise Pollution

Recognizing the detrimental effects of traditional horn systems, researchers and innovators have proposed alternative solutions to reduce noise pollution:

- **Eco-Friendly Horns**: A study introduced an eco-friendly horn system that utilizes short-range radio frequency (RF) communication to transmit horn signals between vehicles. Instead of emitting a loud sound externally, the system alerts the driver of the targeted vehicle through internal indicators, such as dashboard lights or gentle chimes. This approach aims to maintain the functional purpose of horns while minimizing external noise pollution.
- **Infrared-Based Alert Systems**: Another innovative solution involves using infrared (IR) transmitters and receivers installed on vehicles. When a driver activates the horn, an IR signal is sent to the vehicle ahead, triggering an internal alert like an LED light on the dashboard. This method ensures that only the intended recipient is notified, reducing unnecessary noise exposure to pedestrians and other drivers.
- **In-Vehicle Pollution less Horns**: This concept focuses on confining the horn sound within the vehicle's interior, ensuring that only the driver and passengers are alerted. By employing directional speakers and soundproofing techniques, the system prevents horn sounds from escaping the vehicle, thereby reducing environmental noise pollution.

4. Integration of V2V Communication in Horn Systems

The integration of V2V communication in horn systems presents a promising avenue for noise pollution mitigation.

By leveraging the existing CV infrastructure, horn signals can be transmitted digitally between vehicles, ensuring precise and targeted alerts. This method not only reduces external noise but also enhances the effectiveness of horn communication by eliminating ambiguities associated with traditional horn sounds.

Furthermore, incorporating V2V capabilities allows for additional functionalities, such as:

- **Context-Aware Alerts**: Horn signals can be customized based on the driving context, ensuring appropriate responses in different scenarios.
- **Data Logging and Analysis**: Digital horn systems can record usage patterns, enabling authorities to analyse and address issues related to aggressive driving or frequent honking.
- **Integration with Advanced Driver-Assistance Systems (ADAS)**: Combining horn systems with ADAS can facilitate automated responses to potential hazards, further enhancing road safety.

5. Challenges and Considerations

While the proposed innovations offer significant benefits, several challenges need to be addressed:

- **Standardization**: Establishing universal protocols for digital horn communication is essential to ensure interoperability among different vehicle manufacturers.
- **Privacy and Security**: Safeguarding the communication channels against unauthorized access and ensuring user privacy are critical concerns.
- **Public Acceptance**: Educating drivers and the public about the benefits and usage of new horn systems is vital for widespread adoption.
- **Infrastructure Requirements**: Implementing these systems may necessitate upgrades to existing vehicular and road infrastructure, which could entail substantial investments.

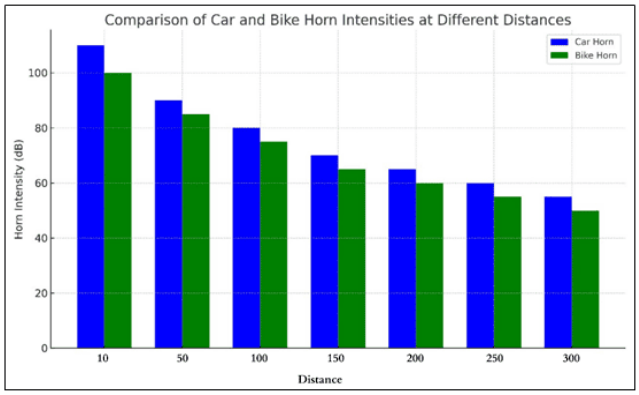
3. Objectives

1. To study the current state of Connected Vehicle (CV) technologies, including Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), and Vehicle-to-Everything (V2X) communication protocols, with a focus on their applications in improving road safety and environmental sustainability.
2. To identify and analyse the contribution of vehicular horn systems to urban noise pollution, and assess the limitations of conventional horn mechanisms in modern traffic environments.
3. To design and develop a novel horn communication system that leverages V2V technology to transmit horn signals digitally between vehicles, allowing the alert to be heard only within the interiors of the target vehicles.
4. To integrate the proposed horn system with existing connected vehicle infrastructure, ensuring secure, real-time, short-range communication that maintains driver awareness while minimizing external noise.
5. To simulate and prototype the system using appropriate hardware and software tools in order to evaluate the effectiveness of the interior-only audible horn system in different traffic scenarios.
6. To assess the environmental and social impacts of the proposed system, specifically focusing on its potential to reduce ambient noise levels in urban areas, thereby improving quality of life for pedestrians and local residents.
7. To propose policy recommendations and implementation strategies for automotive manufacturers and urban planners that support the adoption of noise-reducing connected vehicle technologies.

4. Experimental

a) Measurement of Sound Intensities of Cars and Bikes as a function of distance from the vehicle:

In this project, the sound intensities of horn system were measured (decibel) for two type of vehicles; a passenger car and a bike. The intensities were measured using MECO sound intensity meter. Following graph shows the comparison between the automobile horn sound intensities of a car and a bike:



Graph 1: Horn Sound Intensities of car & bike, measured in dB, as a function of distance

From the graph, it is clear that the intensity of car horn sound is greater than that of the bike horn sound. Hence, the car horn is responsible for larger portion of the noise pollution in the metropolitan cities in the traffic signals and other market yards.

b) Noise Guard Horn System:

In a normal automobile, the horn system is fitted in such a way that its speaker is in the front, near the engine and the driver can press the button fitted at the middle of the steering. The Noise-Guard horn system is almost similar with few upgrades. It simply consists of a radio-frequency transmitter and receiver. When a driver presses the horn on his steering, the transmitter will transmit a RF-signal to the vehicles in its transmission range. The receiver in the receiving vehicle will receive the signal and a sound of horn signal with a suitable loudness will be played inside the interior of the receiving vehicle through its in-built speaker system. In this way, the alert signal would reach only to its target receiver and an undesirable noise pollution can be reduced by implementing such system.

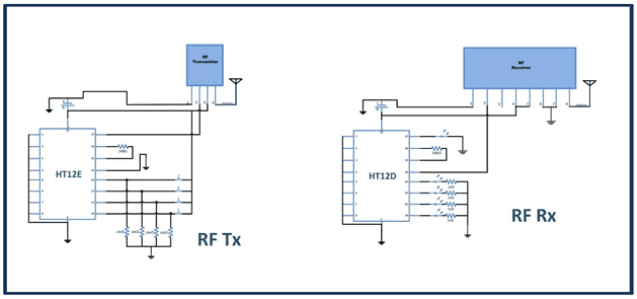


Figure 4: Circuit Diagram of RF Transmitter and Receiver
(Source: https://www.engineersgarage.com/**)**

However, in crowded, unorganized road conditions, as seen in many Asian and some American countries, it is also important to alert people who are walking on the roads, crossing the roads and also who are working on the roads. For this reason, the Noise-Guard must be able to produce a loud sound outside the automobile, just like the traditional horn systems. Therefore, the Noise-Guard is made in such a way that it can produce sound not only in the interior but also at the exterior of the vehicle. The traditional horn system is kept intact and an extra button is added at the middle of the steering so that the driver can choose between two types of horns; interior & exterior. The sample designs are shown below. When needed, the driver can press exterior horn which is similar to the traditional car horn. If the car is stranded near traffic signal where it is not necessary to honk outside, the driver can press the noise-guard button lying at the middle of the steering, thereby alerting nearby connected cars only inside the interior of the car.

Figure 5: Design of Noise-Guard installed in an automobile steering

c) Speed Dependence of Range of Noise-Guard:

The Noise-Guard helps in reducing the noise-pollution produced by automobile horns by about 30% to 50%. But the one aspect that this system needs to take into consideration is "Selectivity", meaning selecting the right vehicle to give an alert. The alert should be received in the vehicle where it is required. For this to happen, the range of the Noise-Guard should be precisely monitored. The Noise-Guard works on a simple principle of transmitting an alert signal through a transmitter and a nearby connected car receives the signal through its receiver. If the vehicle is stuck in traffic, may it be at the traffic signal or at any market yard, it doesn't need to alert vehicles that are far away. It is sufficient to alert 2-3 vehicle ahead of the transmitting vehicle.

On the other hand, if the vehicle is moving at high speeds, maybe on highways, it covers larger distances in small time intervals. Hence the Noise-Guard system needs to alert vehicles that are far away. This means there is a need to program the Noise-Guard in such a way that its range is speed-dependent. When the speed is less, the range should also be small. When the speed is large, the range should also be high.

Figure 6: Small range for lower speeds

Figure 7: Larger range for higher speeds

5. Conclusion

The increasing levels of urban noise pollution, primarily driven by indiscriminate and excessive honking, pose significant health and environmental concerns in metropolitan areas. This research introduced and explored the concept of the Noise-Guard, an innovative interior-only audible horn system integrated within the framework of connected vehicle (CV) technologies. Leveraging Vehicle-to-Vehicle (V2V) communication, this system aims to significantly reduce the propagation of horn noise into the environment while preserving its core functionality of alerting drivers.

The study successfully outlined the technical design and working of the Noise-Guard system, incorporating radio-frequency transmission and speed-dependent dynamic range control to ensure contextual adaptability. Experimental data indicated that conventional horns—especially those in passenger cars—contribute notably to high decibel levels in urban zones, while the Noise-Guard system can effectively reduce this burden by up to 50%. Additionally, the dual-mode system (interior and exterior alert options) ensures safety compliance in diverse traffic environments, including pedestrian-heavy zones or unorganized traffic flows.

This research not only addresses a long-ignored facet of urban noise control but also complements broader smart city initiatives and sustainable mobility goals. The successful integration of Noise-Guard within the existing CV infrastructure showcases its viability as a practical and scalable solution to mitigate vehicular noise pollution.

Suggestions

Policy and Regulation Development:
Governments and urban planning authorities should consider introducing mandatory guidelines for the incorporation of smart horn systems like Noise-Guard in all new vehicles, especially those operating in urban centers. Regulatory standards for digital horn communication protocols could foster industry-wide adoption and interoperability.

Incentivized Adoption:
Automotive manufacturers should be encouraged through tax incentives or environmental credits to adopt and integrate smart horn systems into vehicle designs. Similarly, consumers could be rewarded for retrofitting existing vehicles with Noise-Guard systems.

Infrastructure Support:
While the system primarily operates in a vehicle-to-vehicle mode, integrating it with broader smart infrastructure (e.g., traffic signals, pedestrian zones, public announcement systems) could amplify its effectiveness. Smart intersections could, for instance, notify pedestrians or cyclists via visual or subtle audio cues.

Public Awareness Campaigns:
For successful deployment, widespread public understanding and behavioral adaptation are essential.

Awareness campaigns should educate drivers on the environmental impact of honking and the operational advantages of the Noise-Guard system.

Security and Privacy Safeguards:
As with any connected system, data security is a vital concern. Measures such as encrypted transmission, anonymized logging, and adherence to data protection standards must be embedded in all deployments to protect user privacy and system integrity.

Scalability to Two-Wheelers and Public Transport:
Future research should explore adapting the system to motorbikes, scooters, and public transportation vehicles, which are also major contributors to urban noise pollution. Custom solutions for these categories could broaden the scope and impact of Noise-Guard.

Real-World Pilot Programs:
Municipalities and transport departments should collaborate with academic institutions and manufacturers to run pilot programs in select urban areas. These trials can help fine-tune the technology, gauge user behavior, and quantify the actual reduction in ambient noise.

Integration with ADAS and AI Systems:
The Noise-Guard system can be further enhanced through integration with Advanced Driver Assistance Systems (ADAS) and Artificial Intelligence to automate horn signaling based on predictive modeling of surrounding traffic behavior.

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Writing a research paper is not only a work of intellect but a journey from curiosity to clarity, transforming questions into knowledge through structured inquiry and critical reflection. Walking alone on this path to excellence is almost impossible. My journey is no different. Due to the guidance and support from many of my colleagues, students and my friends, this journey was a joyful event. Writing this research paper has been a deeply enriching experience, and it would not have been possible without the support, encouragement, and guidance of many individuals and institutions. I take this opportunity to sincerely express my heartfelt gratitude. First and foremost, I would like to thank my college for providing a conducive academic environment, resources, and encouragement to pursue this research work.

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References

1. Siegel, J.E., Erb, D.C., & Sarma, S.E. (2018). A survey of the connected vehicle landscape—Architectures, enabling technologies, applications, and development areas. *IEEE Transactions on Intelligent Transportation Systems, 19*(8), 2391–2406.

2. Coppola, R., & Morisio, M. (2016). Connected car: Technologies, issues, future trends. *ACM Computing Surveys (CSUR), 49*(3), 1–36.

3. Ersal, T., Kolmanovsky, I., Masoud, N., Ozay, N., Scruggs, J., Vasudevan, R., & Orosz, G. (2020). Connected and automated road vehicles: State of the art and future challenges. *Vehicle System Dynamics, 58*(5), 672–704.

4. Datta, S.K., Da Costa, R.P.F., Härri, J., & Bonnet, C. (2016). Integrating connected vehicles in Internet of Things ecosystems: Challenges and solutions. in *IEEE 17th International Symposium on A World of Wireless, Mobile and Multimedia Networks (WoWMoM)*, pp. 1–6.

5. Bertoncello, M., Martens, C., Möller, T., & Schneiderbauer, T. (2021). *Unlocking the full life-cycle value from connected-car data*. McKinsey & Company.

6. Xu, Z., Li, X., Zhao, X., Zhang, M.H., & Wang, Z. (2017). DSRC versus 4G-LTE for connected vehicle applications: A study on field experiments of vehicular communication performance. *Journal of Advanced Transportation*, 2750452.

7. Bey, T., & Tewolde, G. (2019). Evaluation of DSRC and LTE for V2X. in *IEEE 9th Annual Computing and Communication Workshop and Conference (CCWC)*, pp. 1032–1035.

8. Gao, S., Lim, A., & Bevly, D. (2016). An empirical study of DSRC V2V performance in truck platooning scenarios. *Digital Communications and Networks, 2*(4), 233–244.

9. Xiong, W., He, S., & Qiu, T.Z. (2017). Research on connected vehicle architecture based on DSRC technology. in *4th International Conference on Transportation Information and Safety (ICTIS)*, pp. 530–534.

10. Al-Fuqaha, A., Guizani, M., Mohammadi, M., Aledhari, M., & Ayyash, M. (2015). Internet of things: A survey on enabling technologies, protocols and applications. *IEEE Communications Surveys & Tutorials, 17*(4), 2347–2376.

11. Basner, M., Babisch, W., Davis, A., Brink, M., Clark, C., Janssen, S., & Stansfeld, S. (2014). Auditory and non-auditory effects of noise on health. *The Lancet, 383*(9925), 1325–1332.

12. World Health Organization. (2018). *Environmental noise guidelines for the European region*. WHO Regional Office for Europe.

13. Stansfeld, S. A., & Matheson, M. P. (2003). Noise pollution: non-auditory effects on health. *British Medical Bulletin, 68*(1), 243–257.

14. 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.

15. Babisch, W. (2006). Transportation noise and cardiovascular risk: Updated review and synthesis of epidemiological studies indicate that the evidence has increased. *Noise & Health, 8*(30), 1–29.

16. Hammer, M. S., Swinburn, T. K., & Neitzel, R. L. (2014). Environmental noise pollution in the United States: developing an effective public health response. *Environmental Health Perspectives, 122*(2), 115–119.

17. Goines, L., & Hagler, L. (2007). Noise pollution: a modern plague. *Southern Medical Journal, 100*(3), 287–294.

18. Munzel, T., Gori, T., Babisch, W., & Basner, M. (2014). Cardiovascular effects of environmental noise exposure. *European Heart Journal, 35*(13), 829–836.

19. Haines, M. M., Stansfeld, S. A., Job, R. F., Berglund, B., & Head, J. (2001). Chronic aircraft noise exposure, stress responses, mental health and cognitive performance in school children. *Psychological Medicine, 31*(2), 265–277.

20. Bronzaft, A. L. (2000). Noise: An insidious health hazard. *Health Environments Research & Design Journal, 1*(1), 47–52.

21. Kwak, Y., & Kim, J. (2019). Design of an electronic horn using PWM for electric vehicles. *Journal of Mechanical Science and Technology*, *33*(2), 541-548.

22. Kim, S., & Lee, D. (2017). Acoustic characteristics analysis of automobile electric horn using CAE method. *International Journal of Automotive Technology, 18*(1), 65-71.

23. Ryu, J., et al. (2015). Reduction of noise pollution from vehicle horns using digital sound synthesis. *Applied Acoustics, 98*, 44-50.

24. Zhao, L., et al. (2020). Intelligent control of automotive horn systems using microcontrollers. *IEEE Transactions on Vehicular Technology, 69*(3), 2672-2679.

25. Garg, N., & Maji, A. (2016). Design optimization of an electromechanical horn for commercial vehicles. *SAE Technical Paper 2016-01-1765*.

26. Li, X., & Wu, M. (2021). Simulation and experimental study of diaphragm-type vehicle horns. *Mechanical Systems and Signal Processing, 148*, 107188.

27. Lee, J. H., & Kim, Y. J. (2018). Development of compact and lightweight automotive horn systems. *Journal of Sound and Vibration, 424*, 142-150.

28. Cheng, H., & Zhang, W. (2019). Development of low-noise horn system for electric vehicles. *Noise Control Engineering Journal, 67*(5), 412-419.

29. Oh, Y., & Park, S. (2022). Analysis and improvement of sound radiation in vehicle horn devices. *International Journal of Vehicle Noise and Vibration, 14*(1), 23-31.

30. Pan, Y., et al. (2017). Numerical and experimental study on electromagnetic acoustic transducers for vehicle horns. *Sensors and Actuators A: Physical, 265*, 25-33.

31. Wang, T., & Liu, H. (2015). A study on vehicle horn sound quality assessment using psychoacoustic parameters. *Applied Acoustics, 91*, 1-7.

32. Kumar, A., & Mishra, P. (2020). Computational analysis of automotive horn system subjected to thermal and vibrational loads. *Journal of Vibration Engineering & Technologies, 8*(1), 145-154.

33. Yamamoto, S., et al. (2014). Development of a new horn system using MEMS technology. *IEEE Sensors Journal, 14*(5), 1368-1373.

34. Chatterjee, S., & Roy, R. (2016). Human perception and annoyance due to vehicle horn noise in Indian metropolitan areas. *Noise & Health, 18*(82), 197-204.

35. Singh, D., & Kaur, M. (2021). Acoustic and mechanical analysis of horn systems in heavy-duty vehicles. *International Journal of Automotive and Mechanical Engineering, 18*(1), 8903-8912.

36. Zhou, Y., & Sun, J. (2018). Application of machine learning to horn failure prediction in automotive systems. *Engineering Applications of Artificial Intelligence, 73*, 128-135.

37. Verma, P., & Sharma, S. (2020). Green horn systems: Exploring alternatives to reduce noise in electric vehicles. *Energy Reports, 6*, 377-384.

38. Kwon, Y., et al. (2023). Biometric horn activation system for intelligent vehicles. *Sensors, 23*(4), 1275.

39. Chen, L., & Gao, F. (2015). Experimental study on horn vibration and its influence on sound pressure level. *Journal of Low Frequency Noise, Vibration and Active Control, 34*(4), 335-343.

40. Tiwari, R., & Dey, S. (2019). Real-time testing and acoustic validation of automotive horn systems. *Measurement, 135*, 231-239.