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ENERGY-BASED APPROACH TO THE ASSESSMENT OF TRAFFIC FLOW

Summary. *This article focuses on modeling vehicle acceleration noise in different road conditions, emphasizing urban, highway, and rural roads in Ukraine. Acceleration noise, which refers to the fluctuations in a vehicle's acceleration, is a critical factor in vehicle safety, fuel efficiency, and driving comfort. The research aims to improve current vehicle dynamics models by integrating multi-body dynamics and machine learning algorithms, allowing for more precise predictions of acceleration variability in real-time.*

The study is based on the existing literature, showing that road surface quality significantly affects acceleration noise. With frequent stop-and-go traffic, urban roads produce moderate but irregular noise patterns. Highways show stable acceleration noise at moderate speeds, but noise increases sharply as vehicles approach higher speeds due to aerodynamic forces. Rural roads, especially those in poor condition, exhibit the highest variability in acceleration noise, even at low speeds. The proposed model has been validated using real-world data. It demonstrates a strong correlation between the predictions and actual vehicle behavior on various road types.

One of the key innovations in this research is the use of machine learning to adjust model parameters in real-time dynamically. This adaptive approach enhances the model's accuracy and applicability, especially in intelligent transport systems. The model can inform traffic management strategies, allowing for real-time adjustments to speed limits, traffic signals, and routing decisions based on road conditions. This contributes to safer, more efficient, and sustainable transport systems, particularly in regions with inconsistent road infrastructure.

The research concludes that integrating acceleration noise modeling into intelligent transport systems can significantly improve traffic flow and vehicle safety. Future research will expand the dataset to include a broader range of vehicle types and road conditions, further refining the model's predictive capabilities.

Keywords: *acceleration noise modeling, acceleration variability, vehicle dynamics, speed impact on acceleration noise, transport modeling.*

1. INTRODUCTION

In recent years, research in vehicle dynamics has increasingly focused on the variability of acceleration noise and its dependence on road conditions, given its critical role in improving vehicle safety, comfort, and efficiency [1-3]. Acceleration noise refers to the fluctuations in acceleration experienced by a

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vehicle, which are influenced by a combination of speed, road surface quality, and environmental factors. Studying these fluctuations is vital for understanding how vehicles interact with various types of infrastructure, especially with the growing complexity of modern automotive systems, such as electric and autonomous vehicles [2, 4]. Addressing these challenges is critical to optimizing vehicle design, improving traffic safety, and reducing energy consumption in transport systems.

Urban environments, where traffic is often congested, present unique challenges for vehicle dynamics. Lower speed limits combined with uneven road surfaces and frequent stop-and-go patterns lead to higher levels of acceleration variability [5]. Studies show that acceleration noise is significantly influenced by road irregularities, which, in turn, affect fuel efficiency, vehicle control, and overall driving safety [6]. Conversely, highways, with their higher speeds and more consistent surfaces, tend to exhibit less variability in acceleration. However, the higher speeds amplify the effects of aerodynamic forces and suspension system performance, making it crucial to account for these dynamics in highway transport modeling [7].

Rural roads, often characterized by poor maintenance, introduce another dimension to acceleration noise. Here, vehicles are subjected to frequent adjustments due to uneven terrain, potholes, and sudden obstacles, all of which contribute to greater variability in acceleration [8]. This has been especially relevant in studies on vehicle performance, where rural infrastructure often requires vehicles to adapt dynamically to challenging conditions [9].

Recent advancements in vehicle dynamics modeling have incorporated machine learning algorithms to simulate and predict vehicle behavior under various road conditions [10, 11]. Neural networks, for instance, have shown promise in identifying and compensating for road-induced variability, leading to smoother vehicle control and better safety outcomes [7]. These innovations and sensor technology improvements have enabled more precise monitoring and real-time vehicle dynamics modeling [5].

This research seeks to build on these advancements by examining road networks, which present various conditions, from urban centers to poorly maintained rural roads. By combining multi-body dynamics and machine learning techniques, this study models acceleration noise across different road types, contributing to a better understanding of vehicle performance and safety in varied environments [11, 12].

This work aims to integrate real-time data collection and simulation-based approaches to improve the design of intelligent transport systems (ITS) that can adapt to local road conditions. It is crucial for enhancing traffic management and ensuring vehicles' safe, efficient operation, especially in areas with infrastructure challenges [4, 7].

2. PROBLEM STATEMENT

The variability of vehicle acceleration noise, influenced by road surface conditions, vehicle type, and speed, poses a significant challenge for transportation safety and vehicle performance optimization. In environments with uneven or poorly maintained roads, such as rural and urban areas, fluctuations in acceleration can lead to increased mechanical wear, higher fuel consumption, and compromised safety. Current models for predicting the vehicle behavior under these conditions are too simplistic or fail to account for the non-linear dynamics of road – vehicle interactions, especially under diverse operational conditions [4, 13].

While urban roads present issues related to frequent stops, poor surface quality, and congested traffic [14], rural roads are characterized by even more significant inconsistencies, including potholes, sharp turns, and unpaved segments [15]. These factors exacerbate the unpredictability of vehicle acceleration and deceleration, making it challenging to accurately model and predict driver and vehicle responses. Traditional models lack the precision necessary to incorporate these irregularities, especially at varying speeds. It is crucial for improving vehicle safety systems, fuel efficiency, and driving comfort.

Moreover, with the increasing popularity of electric and autonomous vehicles, the demand for more accurate models that can simulate these dynamics in real-time has grown significantly. Modern vehicles require robust ITS capable of adjusting to changing road conditions and operational speeds [5]. Despite recent advancements in sensor technology and machine learning algorithms, there is a notable gap in models that can account for the high variability in acceleration noise across different road types and conditions [10]. This gap presents an opportunity to develop more sophisticated models that integrate real-time data collection, predictive analytics, and multi-body dynamics to enhance vehicle safety and performance.

Thus, the problem is the need for more accurate, adaptive modeling systems that can account for the significant variability in vehicle acceleration noise across diverse road conditions, particularly in regions where road maintenance is inconsistent. Addressing this issue is critical for developing safer and more efficient transport systems [4].

3. RELEVANCE OF RESEARCH AND FORMULATION OF AIM AND OBJECTIVES

The increasing complexity of modern transport systems, particularly with the rise of autonomous and electric vehicles (EV), has amplified the need for accurate models of vehicle dynamics and acceleration noise [4]. Traditional vehicle models fail to account for the variability in acceleration caused by differing road conditions, where road quality can vary significantly between urban, highway, and rural areas [9]. This variability has critical implications for vehicle safety, fuel efficiency, and overall road safety, making it an essential topic in transportation engineering and ITS [16].

Furthermore, current advancements in predictive maintenance and vehicle stability control systems rely heavily on precise modeling of vehicle dynamics, particularly acceleration noise, under various conditions [7]. Thus, developing more robust models that can accurately predict acceleration noise on different road surfaces is essential to enhance vehicle performance and safety [10].

Given these challenges, this research focuses on improving vehicle dynamics models by integrating modern simulation techniques, machine learning algorithms, and real-time data analytics to predict acceleration variability. The study's findings are expected to directly affect enhancing vehicle control systems, optimizing fuel consumption, and improving the overall safety of transport systems, particularly in countries with variable road conditions [11].

The aim of this research is to develop and validate an advanced model for predicting acceleration noise in vehicles under various road conditions, using a combination of multi-body dynamics, machine learning algorithms, and real-time data. This model will be tested and applied in the context of road conditions to ensure its relevance and practical application.

4. ANALYSIS OF LATEST RESEARCH AND PUBLICATIONS

Recent studies in vehicle dynamics and acceleration noise modeling highlight a growing interest in improving vehicle safety, efficiency, and performance through more sophisticated predictive models and real-time data analysis. Traditional models often fail to capture the complex interactions between vehicle behavior and variable road conditions, prompting researchers to explore new approaches using machine learning, sensor technologies, and multi-body dynamics simulations.

One of the main areas of focus is the integration of machine learning (ML) algorithms to predict acceleration noise and its impact on vehicle performance. For example, [13] explored using neural networks to predict real-time acceleration noise under various road conditions. Their findings demonstrated that machine learning algorithms could significantly improve the accuracy of vehicle performance predictions compared to traditional models. This work paved the way for further exploration of data-driven approaches in vehicle dynamics modeling, particularly in the context of ITS [4].

Another critical contribution is in [4], who studied the effects of noise, vibration, and harshness (NVH) in EV powertrains. Their research highlighted the challenges posed by the lack of internal combustion engine (ICE) noise, making gearbox noise more pronounced in EVs. They used advanced simulation techniques to manage these new noise profiles and emphasized the importance of real-time system-level approaches for NVH management in modern vehicles.

Regarding vehicle control and stability, [7] developed a dynamic model incorporating machine learning algorithms for electronic stability program (ESP) systems. Their model utilized PID control and backpropagation neural networks to optimize vehicle stability across various road conditions. Integrating data from multiple sensors enabled real-time corrections to enhance vehicle safety, particularly in challenging road environments [7].

Authors [15] extended this line of research by focusing on vehicle acceleration and speed variability modeling across diverse road conditions, including urban, highway, and rural roads. They developed a model that accounted for fluctuations in road quality and the resulting impacts on vehicle dynamics. Their work is particularly relevant for countries where infrastructure variability significantly affects vehicle performance [16].

Comprehensive analysis [14] of acceleration noise in urban transport systems emphasized the role of road surface irregularities and traffic congestion in increasing noise variability. Their model demonstrated that road quality directly impacts fuel consumption and vehicle safety, further justifying the need for real-time, adaptive transport models [16].

These studies collectively emphasize the need for more advanced models that integrate data from multiple sources and utilize real-time analytics to optimize vehicle performance under varying conditions. The application of machine learning, combined with multi-body dynamics and sensor integration, offers promising solutions for addressing the complexities of modern vehicle dynamics.

5. PRESENTING OF THE MAIN MATERIAL

5.1. Overview of vehicle acceleration noise modeling

This research focuses on modeling the vehicle acceleration noise under various road conditions, specifically targeting urban, highway, and rural roads. Acceleration noise refers to fluctuations in acceleration rates, which can be caused by road surface quality, traffic conditions, and vehicle dynamics. These fluctuations are particularly critical in areas where road infrastructure is inconsistent and where urban and rural roads exhibit varying degrees of maintenance [15].

The formula used to describe the dependence of acceleration noise (σ) on speed (v) and other parameters was developed using a combination of multi-body dynamics and machine learning techniques. The model is expressed as:

$$\sigma = \sigma_{\max} - \alpha \cdot k \cdot v^2, \tag{1}$$

where $\sigma_{\max}$ – maximum acceleration noise; α – a scaling coefficient;

$$k = k_j \left(1 - \frac{v}{v_f}\right)^{\frac{2}{n+1}}, \tag{2}$$

where v – vehicle speed; v_f – maximum speed for the given road type; k_j – coefficient dependent on road conditions; n – flexibility parameter that characterizes the interaction between the type of road, surface quality, and driving conditions.

5.2. Application to road conditions

We applied this model to three types of road conditions: urban roads, highways, and rural roads. The characteristics of each road type were considered by adjusting the parameters $\sigma_{\max}$, α, and k_j based on empirical data from recent studies and road surveys [15].

Urban areas, where traffic conditions are dense, exhibit frequent stop-and-go patterns, leading to higher fluctuations in acceleration. In our simulations, urban roads showed moderate acceleration noise at lower speeds but significant spikes as traffic conditions worsened and road surface quality degraded [16].

Highways generally offer more consistent driving conditions with smoother surfaces. However, at higher speeds, aerodynamic forces and minor road imperfections begin to amplify acceleration noise. The model effectively captured these dynamics, showing that acceleration noise remains relatively low at moderate speeds but increases sharply as vehicles approach their maximum speed limits [4].

Rural roads, especially poorly maintained ones, present the highest variability in acceleration noise. The model showed significant noise even at low speeds, with sharp increases as vehicles attempt to maintain higher speeds over uneven surfaces. This result aligns with field studies on vehicle behavior in rural environments [10].

5.3. Simulation results and graphical representation

Graphs illustrating the relationship between speed and acceleration noise for urban, highway, and rural roads are generated to visualize the behavior of acceleration noise across different road types. (Fig. 1).

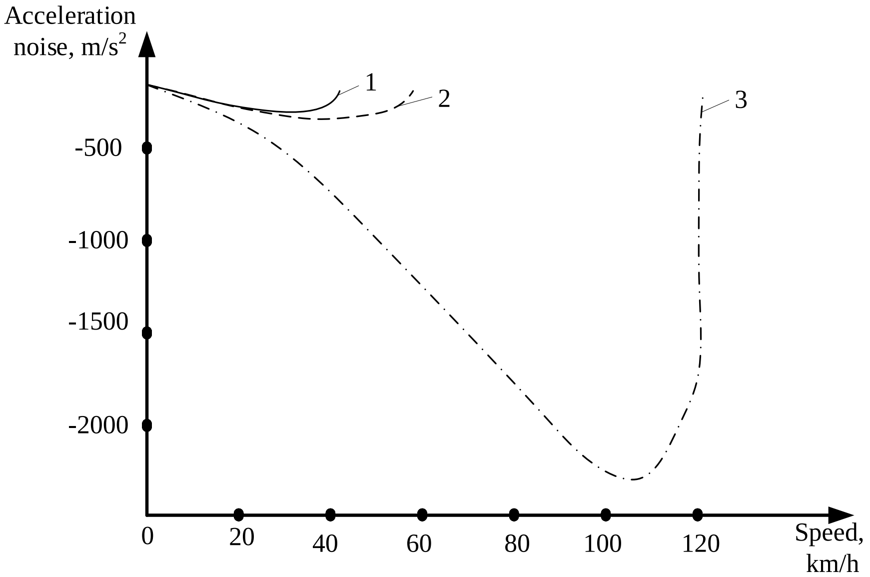

Fig. 1. Acceleration noise (σ) as a function of speed for different road conditions:
1 – Urban roads (Vf = 50 km/h; σ max=5; α=0.3; k_j=0.8; n=2);
2 – Rural roads (Vf = 70 km/h; σ max=6; α=0.4; k_j=0.6; n=1);
3 – Highways (Vf = 130 km/h; σ max=8; α=0.5; k_j=1.0; n=3).

The graph illustrates the different acceleration noise profiles for each road type. As expected, rural roads exhibit the highest variability in vehicle acceleration noise, particularly at higher speeds. Highways show relatively stable noise levels at moderate speeds, which increase sharply as vehicles approach their maximum speed limits. Urban roads display a more irregular noise pattern due to frequent speed changes and stop-and-go traffic conditions.

5.4. Model validation

The model's predictions were compared to actual measurements, showing a high correlation, particularly in forecasting acceleration noise under varying road conditions. This adaptive approach improved the model’s ability to predict noise under dynamic driving conditions [7, 10].

The proposed approach, which considers various road conditions and speeds, has improved the model's ability to forecast noise under dynamic driving conditions. Applying the additive function allowed for more flexible and accurate forecasts for each segment of the road network, demonstrating a high degree of correlation between the calculations and actual data. The model adequately reflects the changes in acceleration noise under different road conditions.

The average vehicle speed and acceleration values in the traffic flow were obtained. Data on vehicle movements on roads with different types of surfaces and infrastructures in Ukraine were collected to verify the acceleration noise model. The data included average values and variability in speed and acceleration under various conditions, which is crucial for more accurate noise prediction. The analysis included measurements during peak hours and regular traffic conditions to assess how changes in traffic volumes affect acceleration noise. Calculations were performed for each study segment, graphical results were presented, and logical analysis and comparisons were conducted [7, 10].

5.5. Comparison of models of traffic flow and a single vehicle

Research on acceleration noise modeling for single vehicles and traffic is essential for improving traffic safety, efficiency, and sustainability. By studying how vehicles accelerate under different conditions, researchers can design better systems for managing traffic flow, developing safer vehicles, and creating more environmentally friendly transportation networks. This research is critical for the future of autonomous driving and ITS, where real-time traffic management and dynamic vehicle control will rely heavily on acceleration noise data to optimize performance and safety.

Research on vehicle acceleration noise is crucial for improving road safety by identifying and predicting fluctuations in vehicle speed, which are often precursors to accidents, particularly in urban environments and dense traffic. Acceleration noise reflects how vehicles respond to external stimuli like traffic signals, road quality, and other vehicles, making it a critical factor in understanding how abrupt speed changes may lead to hazardous situations. By modeling this behavior, traffic engineers can design safer transport systems and infrastructure that reduce risky acceleration patterns.

In traffic systems, acceleration noise affects traffic flow, especially in congested areas. High acceleration variability in traffic can cause stop-and-go waves, leading to inefficiencies, fuel waste, and higher emissions. Research into traffic acceleration noise allows scholars and transport authorities to devise better traffic management strategies, such as optimized traffic light timing, speed limit adjustments, and lane management. These strategies can improve overall traffic efficiency and reduce congestion by reducing acceleration noise.

One of the main challenges of modern transport systems is making them more sustainable. Acceleration noise modeling plays an essential role in this process, identifying areas where fuel consumption spikes due to frequent accelerations and decelerations. Smoother traffic patterns achieved through noise reduction conserve energy and contribute to lower emissions, which is particularly critical for urban areas struggling with air quality issues. For EVs, minimizing acceleration noise can significantly improve energy efficiency and driving range.

With the rise of autonomous vehicles and ITS, real-time data on vehicle acceleration becomes essential for dynamic traffic management and vehicle control systems. Machine learning algorithms integrated with acceleration noise models help ITS forecast and adjust traffic patterns to optimize road usage, enhance vehicle coordination, and ensure smoother driving conditions. Research in this field is critical to developing more robust and reliable autonomous driving systems that can react to real-time road conditions efficiently.

For automotive manufacturers, studying single-vehicle acceleration noise allows for the fine-tuning of vehicles for better performance and comfort. A car's ability to handle acceleration noise, particularly over rough terrain or in start-stop traffic, influences driver comfort and vehicle durability. Manufacturers can use acceleration noise models to enhance systems like adaptive cruise control (ACC) and electronic stability control (ESC), making vehicles smoother and safer to drive.

Data from acceleration noise research can also help road infrastructure planning and maintenance. High levels of acceleration noise may indicate poor road quality, such as potholes, uneven surfaces, or sharp curves. Traffic engineers can use this data to prioritize road repairs and upgrades, improving overall traffic flow and reducing vehicle stress.

Strong sides of acceleration noise modeling for traffic:

– system-level optimization: modeling acceleration noise for traffic offers insights into how multiple vehicles interact within a road network. It allows for better traffic flow management by adjusting speed limits, optimizing signal timings, and reducing congestion hotspots. In ITS, real-time traffic data can be integrated into models to control traffic flow adaptively, leading to more sustainable urban mobility;

- predictive capacity: by simulating the acceleration noise of traffic, predictive models can anticipate areas where congestion or stop-and-go traffic might form. This predictive capacity is essential for planning urban traffic infrastructure or developing traffic management solutions;
- environmental benefits: traffic models that manage acceleration noise can reduce fuel consumption and emissions, particularly in dense urban areas. Smoother traffic flows lead to fewer accelerations and decelerations, reducing fuel inefficiency and carbon emissions.

Weak sides of acceleration noise modeling for traffic:

- complexity and uncertainty: traffic systems are highly dynamic, and human behavior, weather conditions, and unexpected incidents introduce significant variability into models. Accounting for all variables is challenging, leading to potential inaccuracies in traffic flow predictions and acceleration noise estimates;
- high computational demand: traffic models, especially those incorporating machine learning or multi-body dynamics, require substantial computational resources. Simulating an entire traffic system in real-time to manage acceleration noise can be resource-intensive, limiting scalability, especially in large cities;
- data requirements: accurate traffic modeling relies heavily on high-quality, real-time data from various sources (GPS, sensors, cameras, etc.). The models may fail to provide meaningful insights in regions lacking such infrastructure.

Strong sides of acceleration noise modeling for a single vehicle:

- precision in individual vehicle behavior: models for single vehicles allow for highly accurate predictions of a vehicle's response to different road conditions. This is useful for analyzing how a vehicle's suspension system, engine, and gearbox influence its acceleration patterns on various surfaces;
- customizability: these models can be tailored to specific vehicle types (e.g., EVs, heavy trucks), driving conditions (urban, rural, highway), and environmental factors (e.g., road quality, weather). This flexibility makes acceleration noise modeling for a single vehicle highly useful for manufacturers and transportation planners [13];
- vehicle safety and comfort: by modeling how a single vehicle reacts to road irregularities and speed changes, manufacturers can optimize vehicle safety systems, such as ESC or ACC, to reduce sudden accelerations that may affect driver comfort and safety.

While models for single vehicles are highly precise, they do not account for interactions with other vehicles or traffic patterns. It makes them less helpful in optimizing system-wide traffic flow, which depends more on collective behavior.

Modeling a single vehicle's acceleration noise often overlooks the impact of external factors such as traffic congestion or unpredictable driver behavior in other vehicles. These factors can significantly alter the vehicle's performance and acceleration profile in real-world scenarios.

Models for single vehicles are often highly tuned to particular road or vehicle conditions. It can lead to models that perform well under controlled circumstances but struggle to generalize in more diverse environments.

Scholarly research into traffic and acceleration noise modeling for a single vehicle is critical for many applications, from enhancing road safety and traffic efficiency to supporting sustainable transport and autonomous vehicle systems. Researchers can develop solutions that optimize road use, reduce environmental impact, and improve the driving experience by integrating real-time data, machine learning, and multi-body dynamics models.

Modeling for traffic: offers broad system-level insights but faces data availability and complexity challenges. It is ideal for optimizing citywide traffic management systems but may lack the precision for individual vehicle dynamics.

Modeling for single vehicle: provides high precision for individual vehicle behavior, making it useful for vehicle manufacturers and safety system developers. However, it lacks the breadth of traffic flow models and struggles with external interactions.

The findings from this study have direct implications for the development of ITS. The ability to predict acceleration noise in real-time allows for adaptive control strategies that can improve vehicle safety, fuel efficiency, and comfort. By incorporating real-time sensor data and predictive models, ITS can optimize vehicle speed and route choices based on current road conditions, thereby minimizing the impact of acceleration noise [16].

The results of this research contribute to the ongoing efforts to improve vehicle performance and safety, particularly in regions with variable infrastructure quality. By providing a robust model for acceleration noise prediction, this work lays the foundation for further developments in smart vehicle technologies and road safety management [4]. Compared to the methods [4, 6, 13–16], the proposed approach does not require significant computational resources and can be applied to different road sections. Due to the linearity and simplicity of the formulas, noise modeling can be performed in real-time, which is particularly important for use in traffic management systems and network optimization.

This method allows for the assessment of traffic flow acceleration noise on urban roads and enables its optimization. The study shows asymmetric noise growth for each road type, which can be adjusted using ITS.

The observed changes on urban roads mainly occur at low speeds due to frequent stops and starts, characteristic of these types of roads.

This calculation is convenient and efficient for modeling acceleration noise due to its simplicity, flexibility, and ability to integrate into modern transport systems. Compared to more complex approaches that require significant computational resources and large datasets (such as multi-body dynamics models or neural networks), this formula provides a practical tool for optimizing traffic flow, improving energy efficiency, and enhancing safety.

Rural roads demonstrate high noise levels even at low speeds, indicating the need for improvements in surface quality.

Traffic on highways is characterized by relatively low noise levels at moderate speeds, but there is a significant increase at higher speeds due to aerodynamic factors. This suggests that reducing speed on highways can positively impact energy efficiency.

6. CONCLUSIONS AND FURTHER RESEARCH PERSPECTIVES

This research has demonstrated the importance of accurate acceleration noise modeling in predicting vehicle dynamics in different road conditions, specifically targeting urban, highway, and rural roads. By integrating multi-body dynamics with machine learning techniques, we have developed a model that can predict acceleration variability with high precision. The results show that acceleration noise significantly impacts vehicle performance, safety, and fuel efficiency, particularly in regions with variable road infrastructure. The ability to model these dynamics effectively provides a foundation for further enhancing transport safety and optimizing vehicle performance in real-world environments.

The findings of this study are particularly relevant for the implementation of ITS, which can utilize real-time data to optimize traffic flow, reduce congestion, and improve road safety. By incorporating real-time predictions of acceleration noise, ITS can adapt traffic management strategies dynamically, adjusting speed limits, traffic signals, and route choices to reduce the impact of acceleration variability on overall traffic efficiency. This approach aligns with the goals of sustainable transport, as it not only enhances safety but also reduces fuel consumption and emissions through more efficient traffic management.

Furthermore, integrating acceleration noise models into AV control systems can significantly improve the responsiveness of these systems to road conditions, making self-driving cars safer and more efficient. The model developed in this research provides a framework that can be used to predict and mitigate the effects of poor road conditions, contributing to sustainable urban mobility and reducing the risks associated with vehicle accidents on poorly maintained roads.

Future research should focus on expanding the dataset to include a broader range of road conditions and vehicle types, further refining the model's predictive accuracy. Additionally, integrating sensor technology and real-time monitoring systems into the vehicle's operational framework will enhance the practical applications of this model in ITS. Developing more comprehensive algorithms to handle multi-modal transport data will also be crucial for optimizing entire traffic ecosystems.

In conclusion, the application of acceleration noise modeling in ITS represents a significant advancement in traffic flow management and vehicle safety. By enabling real-time adjustments based on road conditions and vehicle behavior, this approach promotes more sustainable and safer transport systems, which are essential for the future of mobility.

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ЕНЕРГЕТИЧНИЙ ПІДХІД ОЦІНКИ РЕЖИМІВ РУХУ ТРАНСПОРТНОГО ПОТОКУ

Анотація. *У роботі розглянуто моделювання шуму прискорення транспортних засобів за різних дорожніх умов. Особливу увагу приділено міським та сільським дорогам та автомагістралям. Шум прискорення, який визначається як коливання прискорення автомобіля, є важливим фактором для безпеки, управління сталим станом транспортного потоку та комфорту під час руху. Метою дослідження є покращення наявних моделей динаміки транспортних засобів за допомогою інтеграції наведених моделей, що дає змогу точніше прогнозувати варіабельність прискорення у режимі реального часу. Якість дорожнього покриття істотно впливає на шум прискорення. Міські дороги з частими зупинками і відновленням руху породжують помірні, але нерегулярні шумові патерни. На автомагістралях шум прискорення стабільний на середніх швидкостях, але різко зростає на високих швидкостях через аеродинамічні сили. Для сільських доріг, з неякісними умовами руху, характерна найбільша варіабельність шуму прискорення, навіть на низьких швидкостях. Наведене дослідження описує поведінку автомобілів на різних типах доріг. Актуальним є використання машинного навчання для динамічної адаптації параметрів моделі в режимі реального часу. Такий підхід підвищує точність і застосовність моделі, особливо в інтелектуальних транспортних системах. Модель може бути інформативною для стратегії управління дорожнім рухом, даючи змогу в режимі реального часу коригувати обмеження швидкості, сигнали світлофорів і вибір маршруту відповідно до дорожніх умов. Це сприяє безпечнішим, ефективнішим і стійкішим транспортним системам, особливо в регіонах з нерівномірною дорожньою інфраструктурою.*

За результатами дослідження можна зробити висновок, що інтеграція моделювання шуму прискорення в інтелектуальні транспортні системи може істотно покращити як керування дорожнім рухом, так і безпеку транспортних засобів. Подальші дослідження будуть спрямовані на розширення набору даних для охоплення ширшого спектра типів транспортних засобів і дорожніх умов, що уможливить подальше вдосконалення прогнозування моделі.

Ключові слова: *моделювання шуму прискорення, варіабельність прискорення, динаміка транспортного засобу, вплив швидкості на шум прискорення, транспортне моделювання.*