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TRAFFIC FLOW MODEL WITH INFLUENCE OF PASSENGER TRANSPORT

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ABSTRACT

This work deals with accomplishing the first objective of the research. It is determined that passenger route traffic can be divided into traffic by city roads and traffic by country roads. Outside cities vehicles use mostly public roads with two or four lanes. Country roads with four lanes are characterized by the following features: there are no obstacles like crossroads with pedestrian crossings at the same level; traffic ban is applied to certain road users; top speeds can be formed; there are accidents with route vehicles involved.
There is substantial analysis of the statistical data concerning accidents with route vehicles involved on public roads, and the accidents mentioned are characterized by significant severity. The number of people who are injured or die in the result of one road accident with a passenger route vehicle involved is significantly bigger as compared to other kinds of road accidents. The accidents under discussion are characterized by extreme severity in conditions of high speeds on public roads as compared to road sections of other types. All this demonstrates the relevance of the direction that has been chosen for scientific research.
Passenger route traffic safety is indirectly taken into account only when the route is planned and the indicator is added to the route passport. The information that the route passport provides refers to existing rail crossings and traffic accident areas. These specified elements are entered into the route scheme and are cited as a list. At present there are no tools to calculate the degree of danger; also there are no methods to organize a route that takes into account passenger route traffic safety on route sections as part of the relevant traffic flows. With the existing accidents statistics and corresponding severity indicators taken into account, the scientifically practical objective to develop a method to estimate passenger route traffic safety on public roads is clear. In accordance with the task proposed, the object, the subject, the goal and objectives of the research have been formulated in the article.
For every level of the traffic flow analysis, a theoretical basis for forming traffic safety of passenger route vehicles within their interaction with other vehicles in the traffic flow has been formulated. It has been proposed to reveal negative phenomena which precede road accidents and occur in the traffic flow due to passenger route vehicles traveling at a set speed and at set intervals. These phenomena should be represented as deviations in kinematic characteristics of the traffic vehicles flow from similar characteristics of the passenger route vehicles flow.

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Introduction.

Passenger route traffic is a vital element of contemporary transportation systems, playing a significant role in connecting urban and rural areas while supporting economic and social activities. It facilitates mobility for millions of people daily, ensuring access to workplaces, education, healthcare, and leisure. Despite its undeniable importance, passenger route traffic is also one of the most vulnerable components in terms of safety.

A significant challenge arises from the high accident rates involving passenger route vehicles, especially on high-speed country roads. These roads are characterized by specific features, such as the absence of level pedestrian crossings, restricted access for certain categories of road users, and the allowance for vehicles to achieve maximum speeds. These factors create conditions conducive to severe traffic accidents, often resulting in catastrophic outcomes. Statistical data indicate that accidents involving passenger route vehicles tend to result in a significantly higher number of fatalities and serious injuries compared to other types of road incidents. This disparity underscores the critical need to focus on improving the safety of passenger route traffic [1].

Current traffic management practices address passenger route safety indirectly. Measures such as route passports provide some safety-related information, such as the location of rail crossings and accident-prone zones. However, these tools are insufficient for comprehensive safety evaluations. They lack methodologies to assess the degree of danger on specific route sections or strategies to optimize routes based on passenger safety considerations. As a result, the planning and operation of passenger routes do not fully address the inherent risks posed by high-speed conditions and mixed traffic environments.

This research explores the interplay between traffic flow dynamics and passenger vehicle safety, emphasizing the need for a systematic approach to mitigating risks. The study aims to identify the underlying factors that contribute to traffic accidents involving passenger route vehicles and propose a framework for evaluating and enhancing safety measures. By focusing on the kinematic characteristics of traffic flows and their deviations, the research seeks to develop practical tools for improving route planning and traffic management. This approach not only addresses existing safety challenges but also lays the groundwork for more robust and efficient transportation systems [2 –4].

In summary, the importance of passenger route traffic to modern societies is undeniable. However, the associated safety risks demand immediate and comprehensive attention. This study contributes to the ongoing effort to enhance road safety by proposing innovative methodologies and frameworks for understanding and mitigating the risks associated with passenger route traffic.

Methodology.

The methodology of this research is grounded in a multi-faceted approach to evaluating and enhancing the safety of passenger route transport on public roads. At its core, the methodology integrates theoretical modeling, statistical analysis, and experimental validation to address the critical issues of traffic safety, particularly for passenger transport in mixed traffic conditions. The primary aim was to identify the underlying factors contributing to traffic incidents involving passenger vehicles and develop tools to mitigate these risks.

The analysis began with a thorough examination of accident trends involving passenger route vehicles on highways and public roads. The data revealed a consistent pattern of disproportionately severe accidents associated with high-speed conditions and mixed traffic flows. Roads with two or more lanes were identified as particularly hazardous due to the absence of speed restrictions, leading to higher casualty rates and more significant property damage compared to urban streets. The analysis highlighted a critical gap in existing safety planning measures, such as route passports, which fail to address the specific safety needs of passenger transport vehicles [5 – 7].

Building on these insights, the research focused on the kinematic dynamics of passenger vehicles within traffic flows. Deviations in speed and spacing between vehicles were identified as critical precursors to accidents. Passenger vehicles often operate at regulated speeds that differ significantly from the average speed of the surrounding traffic, creating instability and increasing the likelihood of collisions. The study also identified high-risk conflict zones, such as merging and overtaking sections, where abrupt changes in vehicle behavior and speeds were most likely to result in accidents.

To address these issues, a novel target function was developed to quantitatively assess the safety of passenger route transport. This function evaluates safety conditions on a scale from 0 to 1, with values closer to 1 indicating higher safety levels. The function incorporates kinematic and energy-based metrics, such as speed, acceleration, and density deviations, to predict and analyze accident likelihood. It serves as a reliable tool for identifying high-risk areas and formulating safety interventions [8].

The methodology also included experimental validation of the target function on a real-world road segment. The M-30 public road was selected as the experimental site, covering sections with varying traffic conditions and accident histories. The results confirmed the accuracy and applicability of the target function in predicting accident-prone areas. It demonstrated the ability to assess and improve safety conditions through targeted interventions, such as optimizing vehicle spacing, harmonizing speeds, and enforcing lane discipline [9].

Furthermore, the study proposed practical measures for enhancing passenger route safety. These include dynamic route optimization using real-time traffic data, infrastructure improvements like dedicated lanes and improved signage, and driver training programs emphasizing defensive driving and adherence to traffic regulations. These recommendations aim to address the specific challenges faced by passenger transport vehicles, ensuring their safe integration into mixed traffic environments.

The methodology's holistic approach combines macroscopic, microscopic, and engineering-psychological perspectives, offering a comprehensive framework for traffic safety analysis. By integrating theoretical models with experimental validation and practical applications, this research provides a robust foundation for reducing accidents and enhancing the safety of passenger route transport on public roads [10].

To address the safety challenges associated with passenger route traffic, a comprehensive research methodology was designed, combining statistical analysis, traffic flow evaluation, and the development of a safety framework. Each methodological component focuses on identifying, analyzing, and mitigating risks to passenger route vehicles in both urban and rural environments. The methodology ensures a holistic approach to traffic safety, enabling the generation of actionable insights and practical tools for transportation management.

1. Analysis.

The first phase of the research involves an in-depth investigation of traffic accident data related to passenger route vehicles. This analysis aims to identify key patterns, risk factors, and severity indicators that characterize accidents involving these vehicles. Key steps in this phase include:

Data Collection. Accident records were gathered from public road databases, transportation agencies, and law enforcement reports. The data included information on accident locations, vehicle types, speed conditions, and the number of casualties.

Classification of Accidents. Accidents were categorized based on their severity (e.g., minor, serious, fatal), location (urban roads, rural highways), and contributing factors (e.g., driver behavior, road conditions, vehicle malfunction).

Trend Analysis: Statistical techniques were applied to determine recurring trends, such as peak times for accidents, high-risk road sections, and common causes of collisions.

Findings from this phase reveal that accidents involving passenger route vehicles are significantly more severe on high-speed rural roads compared to urban areas. Furthermore, these accidents frequently occur in mixed traffic conditions where differences in vehicle speeds and behaviors exacerbate risks.

2. Traffic Flow Characteristics.

The second phase focuses on analyzing traffic flow dynamics, specifically examining the kinematic characteristics of passenger route vehicles and their interaction with other vehicles. This analysis aims to understand how deviations in traffic flow contribute to accident risks.

The speeds, accelerations, and spacing of passenger route vehicles were compared to those of surrounding traffic. Deviations from expected kinematic norms were identified as potential precursors to accidents.

Microscopic traffic simulation models were used to replicate real-world traffic conditions, allowing for the observation of interactions between passenger route vehicles and other road users. Simulations were conducted under various scenarios, including high-speed rural highways and congested urban streets.

Scenarios where deviations in speed or spacing led to unsafe conditions were documented. These included instances where passenger route vehicles were forced to brake suddenly due to erratic behavior by other road users or when high-speed differentials created unstable traffic flow patterns [12].

3. Safety Framework Development.

Building on the insights gained from statistical analysis and traffic flow evaluation, the study proposes a framework for assessing and enhancing passenger route traffic safety. The framework integrates real-time data analysis with proactive safety measures to mitigate risks.

A quantitative model was developed to evaluate the degree of danger on specific route sections. The model incorporates factors such as accident history, traffic flow deviations, road design, and environmental conditions.

Key performance indicators (KPIs) were defined to measure safety levels, including accident rates, severity indices, and the frequency of kinematic deviations.

The framework includes tools for adaptive route planning, which use real-time data to identify safer routes and avoid high-risk areas. These tools prioritize passenger route vehicles by considering their unique operational requirements, such as consistent speeds and fixed intervals [12].

4. Data Collection and Validation.

Data were collected from public roads in both urban and rural settings to ensure the findings are applicable across diverse traffic conditions. The data collection process involved:

Traffic monitoring was conducted at selected locations using high-resolution cameras and speed sensors. These observations provided detailed information on vehicle interactions, speeds, and spacing.

Partnerships with transportation agencies and local governments facilitated access to traffic data and accident records.

The proposed framework and models were validated using simulation software, ensuring their reliability and applicability in real-world scenarios [13].

5. Ethical Considerations.

Throughout the research process, ethical guidelines were strictly followed to ensure data privacy and transparency. Accident data were anonymized to protect the identities of individuals involved. The findings and recommendations were shared with relevant stakeholders, including policymakers and transportation planners, to support evidence-based decision-making.

6. Applicability and Scalability.

The methodology was designed to be scalable and adaptable, allowing it to be applied to various traffic conditions and geographic locations. The insights gained from this research are intended to support the development of safer transportation systems worldwide, addressing both current challenges and emerging risks [14].

Conclusion.

This dissertation addresses the urgent issue of enhancing the safety of passenger route transport on public roads, particularly on highways and multi-lane roads. Passenger transport is an essential part of the transportation system, but its unique characteristics and operational challenges make it especially vulnerable to accidents. Statistical analysis confirms that public roads with two or more lanes exhibit the highest severity of accidents involving passenger vehicles. These incidents are often more severe than other types of road accidents due to factors such as higher vehicle speeds, varying traffic densities, and the complexity of mixed traffic interactions. The study identifies a significant gap in existing methodologies, which often fail to address the specific safety challenges posed by passenger route transport. While traditional traffic safety measures focus on general road conditions, they rarely consider the dynamic interactions between passenger vehicles and the surrounding traffic flow. This research bridges this gap by introducing a comprehensive model for evaluating and enhancing the safety of passenger route transport.

A key achievement of this study is the development of a mathematical model that quantifies the safety of passenger transport operations. This model captures deviations in energy and kinematic parameters, providing a holistic assessment at macroscopic, microscopic, and engineering-psychological levels. By integrating these dimensions, the model enables precise identification of high-risk areas and factors contributing to accidents. The research also introduces a target function that assesses safety levels on a scale from 0 to 1, where values closer to 1 indicate higher safety. Experimental validation of this function on the M-30 public road demonstrated its reliability and practical applicability. The function successfully identified high-risk sections and provided actionable insights for improving safety conditions.

The study goes beyond analysis by proposing a methodology to enhance passenger transport safety. This methodology emphasizes real-time assessment and adjustment of vehicle dynamics, such as harmonizing speeds and promoting consistent lane adherence. By minimizing deviations from optimal traffic flow conditions, the methodology significantly reduces accident risks. Its experimental implementation confirmed its effectiveness in enhancing the safety of passenger route transport.

The practical implications of this research are substantial. Policymakers are encouraged to integrate the proposed target function into national traffic safety frameworks to standardize safety assessments for passenger route transport. Infrastructure improvements, such as dedicated lanes, improved signage, and real-time monitoring systems, are also recommended. These measures will help create safer and more efficient traffic environments for passenger vehicles. The study's findings have already been applied in real-world projects, including implementation by "Kyivdormistproekt" and the National Institute for Infrastructure Development. These applications demonstrate the scalability and adaptability of the proposed methodologies.

Additionally, the study has contributed to education by enriching academic curricula with advanced tools and methodologies for traffic safety management. This ensures that future professionals in transportation and logistics are equipped to address the complex challenges of road safety. Despite its significant contributions, the study acknowledges certain limitations, such as the need for broader datasets to validate the model across diverse traffic environments and road types. Future research should also explore the integration of emerging technologies, such as connected vehicles and artificial intelligence, to enhance real-time safety management. Long-term evaluations of the methodology's impact on accident reduction across various regions will further validate its effectiveness.

In conclusion, this dissertation makes a meaningful contribution to transportation safety by addressing the unique challenges of passenger route transport. The proposed methodologies and tools not only provide theoretical advancements but also offer practical solutions for policymakers, transportation planners, and industry stakeholders. By improving the safety of passenger transport systems, this research contributes to the broader goal of creating safer and more efficient transportation networks. Its findings set a foundation for continued innovation and development in the field of traffic safety.

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