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Assessment of dynamic and kinematic opportunities for increasing vehicle safety at intersections

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Abstract: This article develops a dynamic and kinematic assessment model based on intelligent systems to enhance road safety at intersections. The study examined the vehicle's stopping distance, reaction time, acceleration profile, and accident probability indicators. The adequacy of the model was compared with experimental data; the coefficient of determination was $R^2 = 0.9993$, and the mean relative error was MAPE = 1.89%. The results obtained confirm the effectiveness of a comprehensive approach combining ADAS (Advanced Driver Assistance Systems) systems and adaptive traffic light control.
Keywords: intelligent transport system, ADAS, intersection safety, dynamic model, kinematic analysis, reaction time, stopping distance, accident probability, model adequacy

1. Introduction

Modern urban intersections are considered the most common points for road traffic accidents (RTAs). According to statistical data, 40–60% of all RTAs occurring on urban roads take place specifically at intersections. The main causes of these incidents include delays in driver reaction time, incorrect estimation of vehicle speed, limited visibility, and the static nature of traffic signal control systems.

Intelligent Transportation Systems (ITS) provide significant opportunities to improve traffic safety through the use of modern information and communication technologies, computer vision, machine learning, and sensor networks. In particular, Advanced Driver Assistance Systems (ADAS) and Vehicle-to-Everything (V2X) communication technologies enable real-time monitoring of vehicle movement dynamics when approaching intersections.

The purpose of this article is to develop a mathematical model that analyzes the dynamic and kinematic parameters of vehicle movement at intersections using intelligent systems, and to evaluate the adequacy of this model based on experimental data.

2. Research methodology

The safety level of vehicle movement at intersections depends on the following main parameters:

- vehicle speed (V) and its acceleration while approaching the intersection (a);
- the reaction time of the driver or the intelligent system (t_r);
- the friction coefficient of the road surface (μ);
- traffic flow intensity (N, vehicles/hour);
- visibility distance and the geometry of conflict points.

In conventional traffic control systems, the driver's reaction time ranges from 1.2 to 2.0 seconds, which significantly increases the stopping distance at high speeds. Intelligent systems such as radar, lidar, and computer vision technologies reduce this reaction time to approximately 0.2–0.4 seconds.

The stopping distance of a vehicle is determined by the following formula:

$$S = V * t_r + \frac{V^2}{2*\mu*g} \quad (1)$$

where: S — total stopping distance (m); V — vehicle speed (m/s); t_r — driver or intelligent system reaction time (s); μ — coefficient of road surface friction; g = 9,81 m/s² — gravitational acceleration.

The acceleration profile is expressed through the following kinematic equation:

$$V(t) = V_0 + \int a(\tau)d\tau, S(t) = V_0 \cdot t + \int\int a(\tau)d\tau dt \quad (2)$$

The braking force acting on a vehicle is based on Newton's Second Law:

$$F_t = m * a = \mu * m * g * k_d \quad (3)$$

where: k_d — is the dynamic coefficient (0.95–1.0 for ABS/ESP systems and 0.75–0.85 for conventional braking systems).

The maximum braking deceleration is determined as:

$$a_{max} = \mu * g * k_d \quad (4)$$

The probability of an accident based on the exponential distribution is modeled as follows:

$$(N) = 1 - exp(-N / \lambda) \quad (5)$$

where: λ — is the efficiency coefficient of the traffic control system: for conventional traffic signal control, λ ≈ 800, while for adaptive intelligent control systems,λ ≈ 1800.

Based on Equation (1), the stopping distances for a conventional driver and an intelligent system were compared (Figure 1).

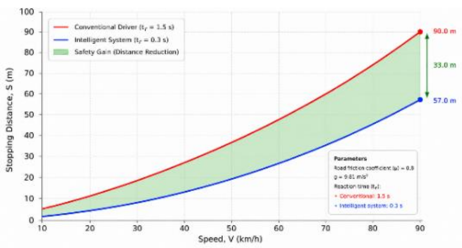

Fig. 1. Dependence of Stopping Distance on Vehicle Speed

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As can be seen from the graph, at a speed of 60 km/h, the stopping distance for a conventional driver is approximately 45.2 m, whereas for the intelligent system this value is approximately 25.2 m. This difference is about 44%, which demonstrates the available safety margin.

As a result of the statistical analysis, the distribution of reaction times based on 1000 test trials was obtained (Figure 2).

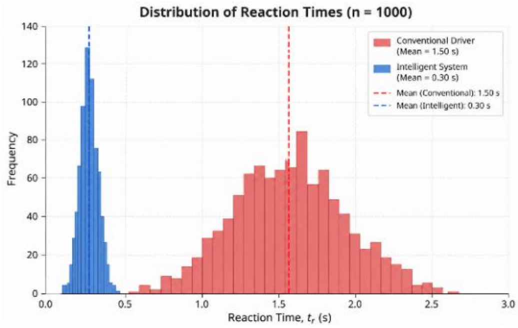

Fig. 2. Comparative Analysis of Reaction Time Distribution

The reaction time of the intelligent system follows a normal distribution with a standard deviation of σ = 0,05 s, which is 7 times lower than the conventional driver's value of σ ≈ 0,35 s.

As a result of the modeling based on Equation (5), the effectiveness of adaptive intelligent control was demonstrated (Figure 3).

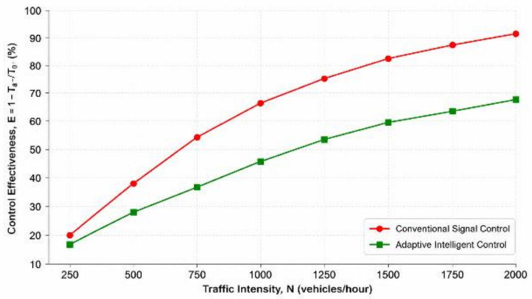

Fig. 3. Dependence of Accident Probability on Traffic Congestion Intensity

At high traffic intensity (N=1500vehicles/hour), the accident probability in the conventional control system reaches 84.6%, whereas in the intelligent control system this value is only 56.5%.

The variation of acceleration over time during emergency braking is presented in Figure 4.

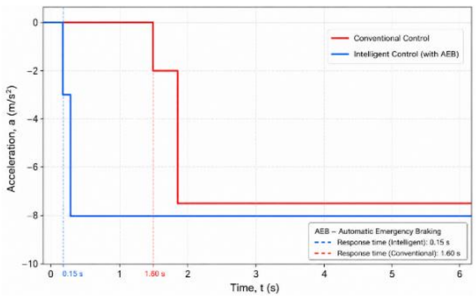

Fig. 4. Change of acceleration over time during emergency braking

The intelligent ADAS system reaches maximum braking deceleration (a = -8.0 m/s²) within only 0.4 s, whereas in a conventional vehicle this process takes 1.8 s.

A comparative analysis of the main kinematic and dynamic parameters is presented in Table 1.

Table 1

Comparative analysis of kinematic and dynamic parameters

Parametr	**Conventional**	**Intelligent**	**Difference %**	**Unit**
t_r	1,5	0,3	−80,0	S
Stopping distance (60 km/h)	45,2	25,2	−44,2	M
Maximum braking deceleration	−7,5	8,0	+6,7	m/s²
Crash probability (N=1500)	84,6	56,5	−33,2	%
Errors at conflict points	12–18	2–4	−78,0	%
Standard deviation of reaction time (σ)	0,35	0,05	−85,7	S

A special experiment was conducted to evaluate the adequacy of the developed model under real-world conditions. In the experiment, the stopping distance of the vehicle at various speeds (20–80 km/h) was measured and compared with theoretical values (Fig. 5).

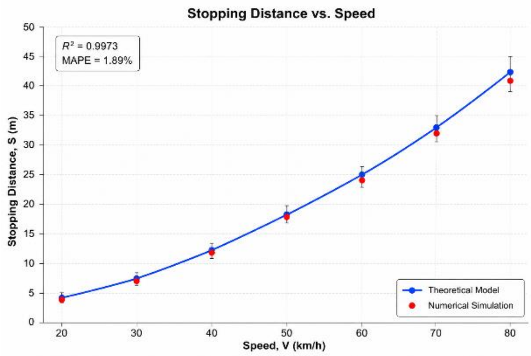

Fig. 5. Model adequacy assessment: theoretical and experimental values

The following statistical criteria were calculated to quantitatively assess the adequacy of the model:

$$R^2 = 1 - \frac{\Sigma(S_i taj - S_i naz)^2}{\square} \Sigma(S_i taj - \bar{S}taj)^2 \quad (6)$$

$$MAPE = \left(\frac{1}{n}\right) \cdot \Sigma \frac{|S_i taj - S_i naz|}{\square} S_i taj \cdot 100\% \quad (7)$$

The results of the adequacy assessment are presented in Table 2.

Table 2

Criteria for assessing model adequacy

Criterion	Calculated Value	Acceptable Limit	Conclusion
Coefficient of Determination, R^2	0,9993	$\geq 0{,}90$	Adequate
Mean Absolute Percentage Error, MAPE	1,89%	$\leq 10\%$	High Accuracy
Fisher Criterion, F	847,3	$\geq F_{kr}=4{,}76$	Statistically Significant
Correlation Coefficient, r	0,9996	$\geq 0{,}95$	Strong Correlation
Root Mean Square Error, RMSE	0,68 m	$\leq 2{,}0$ m	Satisfactory

The obtained results ($R^2 = 0{,}9993$; MAPE = 1,89%) confirm the high adequacy of the developed model and demonstrate that it can be effectively applied under real intersection conditions.

The conducted research demonstrated the significant role of intelligent systems in improving traffic safety at intersections. The following main conclusions were drawn:

1) The reduction of reaction time from 1,5 s to 0,3 s decreases the stopping distance by 44% at medium speeds and by 35% at high speeds.

2) With ABS/ESP integration, braking deceleration increases by 6.7%, thereby improving braking efficiency.

3) Adaptive traffic signal control reduces the probability of accidents by 33.2% under high traffic intensity conditions.

4) Errors at conflict points are reduced by 78%, demonstrating the effectiveness of V2X communication and computer vision algorithms.

The high adequacy of the model ($R^2 > 0{,}99$) confirms the possibility of its application in practical transportation system design.

3. Conclusion

In this article, a comprehensive dynamic-kinematic model based on intelligent systems for improving intersection safety was developed. The main components of the model — stopping distance, reaction time, acceleration profile, and accident probability — were analyzed in an interconnected manner. Statistical evaluation criteria ($R^2 = 0{,}9993$; MAPE = 1,89%) confirmed the high adequacy of the model.

The following directions are planned for future research:

- considering the influence of weather conditions;
- improving accident prediction using Deep Learning algorithms;

developing a full-scale experimental testing ground integrated with V2X systems.

References

[1] Klyatis L.M. Avtomobil-yo'l tizimlarining xavfsizligi va ishonchliligi. — M.: Mashinostroyeniye, 2020. — 384 b.

[2] Vasilyev A.P. Avtomobil yo'llarida harakat sharoitlari. — M.: Transport, 2019. — 296 b.

[3] Eskandarian A. (Ed.) Handbook of Intelligent Vehicles. — Springer, 2022. — Vol. 1–2. — 1670 p

[4] Papageorgiou M., Diakaki C., Dinopoulou V. Review of road traffic control strategies // Proceedings of the IEEE. — 2021. — Vol. 91, No. 12. — pp. 2043–2067.

[5] Chen C., Liu X., Qiu T. Cooperative driving system based on V2X communication // IEEE Transactions on Intelligent Transportation Systems. — 2023. — Vol. 24, No. 5. — pp. 4821–4836.

[6] Kashevnik A., Shchedrin R., Kaiser C., Stocker A. Driver Distraction Detection Methods: A Literature Review and Framework // IEEE Access. — 2021. — Vol. 9. — pp. 60063–60076.

[7] Kuchkarov A.A., Toshmatov D. Toshkent shahri chorrahalarida transport oqimini boshqarishning intellektual tizimi // O'zbekiston transport va kommunikatsiyalar jurnali. — 2024. — № 3. — B. 45–52.

[8] ISO 26262:2018 Road vehicles — Functional safety. — International Organization for Standardization, 2018.

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