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ANALYSIS OF CONTEMPORARY METHODS FOR ORGANIZING SAFE TRAFFIC AT INTERSECTIONS

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Annotation. *This scientific article is dedicated to the analysis of modern approaches aimed at ensuring safety and improving transportation efficiency at urban intersections. The main focus is on the "Safe System Approach" philosophy, Intelligent Transport Systems (ITS), adaptive traffic light control, Vehicle-to-Everything (V2X) communication technologies, and Artificial Intelligence (AI). The analysis results demonstrate the effectiveness of these approaches in reducing the rate of traffic accidents (TA), optimizing congestion, and creating a safe environment for all road users (vehicles, pedestrians, cyclists).*

Keywords: *Safe System, adaptive traffic signal, ITS, V2X, intersection safety, AI, transport analysis.*

Intersections are the primary nodes of urban road networks and play a crucial role in regulating traffic flow. However, they are also locations with a high probability of collisions between vehicles and pedestrians. While traditional approaches (timed traffic signals, standard geometry) have demonstrated limited effectiveness, modern technologies and systematic strategies offer new solutions to this problem. The aim of this article is to analyze the latest and most effective methods for organizing intersection safety.

The “Safe System” approach (a central component of the Vision Zero principle) represents a paradigmatic shift in ensuring traffic safety. It acknowledges human error as inevitable and focuses on enhancing the system’s resilience to such errors, ensuring that it is forgiving and minimizes the consequences of mistakes.

Table 1.

Influence of Key Pillars on Intersection Design

Pillar	Implementation at Intersections	Impact on Safety (Analysis)
Safe Speed	Incorporation of speed-reducing elements (e.g., lane narrowing at entry points), roundabouts.	Incorporation of speed-reducing elements (e.g., lane narrowing at entry points), roundabouts.
Safe Roads	Replacement with roundabouts (eliminates right-angle	Replacement with roundabouts (eliminates right-angle collisions),

	collisions), pedestrian refuges, dedicated turning lanes.	pedestrian refuges, dedicated turning lanes.
Safe Road Users	Education, mandatory regulations, intelligent monitoring.	Education, mandatory regulations, intelligent monitoring.

Analysis: The Safe System approach aims to fundamentally reduce the severity of collisions at intersections through geometric design. For instance, replacing traditional signalized intersections with roundabouts has been scientifically shown to reduce severe collisions by an average of 70–80%.

Modern technological solutions enable real-time intersection management, allowing simultaneous optimization of both safety and efficiency.

Adaptive control systems (e.g., SCATS, SCOOT) abandon pre-set signal timing cycles. Instead, they dynamically adjust signal timings based on real-time traffic flow data collected from sensors such as radar and video detectors.

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Analysis: Adaptive systems are capable of reducing congestion by 20–30%. From a safety perspective, they mitigate driver impatience and attempts to run red lights, which often occur due to excessive delays.

Modern AI methods, particularly Machine Learning (ML) and Deep Learning (DL), have elevated safety analysis at intersections to a new level:

- Collision Prediction: AI algorithms use video surveillance data to detect potentially dangerous maneuvers in real time, such as sudden braking, unsafe turns, or pedestrians crossing at inappropriate locations.
- Risk Forecasting: Based on historical crash data, weather conditions, and traffic flow parameters, ML models predict the probability of accidents at a given intersection at a specific time. This enables automatic adjustment of traffic signal operations to prioritize safety.

Vehicle-to-everything (V2X) communication technology represents one of the most promising directions for enhancing intersection safety.

V2X includes two main types of communication:

- V2I (Vehicle-to-Infrastructure): Data exchange between vehicles and intersection infrastructure (Roadside Units – RSUs). RSUs provide vehicles with information about signal timings, speed advice (GLOSA – Green Light Optimized Speed Advisory), and queue status.
- V2V (Vehicle-to-Vehicle): Direct communication between vehicles.

Table 2.

Impact of V2X Functions on Safety

V2X Function	Impact on Safety
Intersection Collision Warning (ICW)	Provides real-time alerts to the driver about potential collisions at right-angle or turning movements. Mitigates driver errors.
Green Light Optimized Speed Advisory (GLOSA)	Advises the driver on the optimal speed to pass through the intersection without stopping.
Pedestrian Safety Warning (V2P)	Alerts the vehicle about pedestrians in areas not visible to the driver.

In conclusion, the analysis of modern approaches to ensuring safe traffic at intersections demonstrates that effective solutions are achieved not through a single method, but through comprehensive integration. The Safe System approach guarantees a fundamental reduction in the severity of collisions by adapting intersection geometry and vehicle speeds to human biological limits. Information and Communication Technologies (ICT), Artificial Intelligence (AI), and V2X technologies enable real-time risk detection and active management, thereby preventing accidents and optimizing traffic flow. In the future, with the introduction of autonomous vehicles, V2X communication will allow intersections to be fully monitored virtually, representing the highest level of intervention aimed at minimizing both congestion and accidents to near zero.

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