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Review

The Impact of Intelligent Transport Systems on Safety, Emissions Reduction, and Travel Time: A Review

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Abstract

The intensive development of road transportation and the increasing number of vehicles have led to significant challenges related to road safety, traffic congestion, travel time, energy consumption, and negative environmental impacts. In this context, intelligent transport systems (ITS) represent a significant approach to improving the efficiency and sustainability of modern transportation systems. The aim of this paper is to present and systematize the application of modern ITS technologies for improving road safety, reducing emissions, and shortening travel time. Based on an analysis of the relevant literature, the fundamental components and architecture of ITS are presented, including sensor systems, V2X communication, IoT, cloud and edge computing, as well as the application of artificial intelligence in traffic data processing and prediction. The analyzed studies demonstrate that ITS enables dynamic traffic flow management, route optimization, reduction in congestion and emissions, and more efficient responses to emergency situations. Particular attention is devoted to the possibility of simultaneously considering travel time, energy consumption, emissions, noise, and road safety. As a synthesis of the analyzed findings, an integrated algorithm for intelligent traffic management is proposed, operating as a closed feedback loop encompassing data collection, state assessment, prediction, optimization, and control. Future ITS development is expected to focus on the integration of AI, IoT, 6G, and edge computing technologies and their validation using real-world traffic data.

Keywords: intelligent transport systems; traffic safety; artificial intelligence; traffic management; sustainable transportation

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1. Introduction

1.1. Basic Facts About the Impact of Vehicles

The automobile is the primary mode of personal and commercial transportation for people worldwide [1,2]. In 2024, the European Union recorded 574 cars per 1000 inhabitants [3]. However, the widespread use of motor vehicles has resulted in serious and unforeseen negative consequences that directly threaten human health and the environment while exacerbating social inequality. From a road safety perspective, global transportation is facing a major crisis: approximately 1.19 million people lose their lives in road traffic accidents each year, while between 20 and 50 million sustain non-fatal injuries ranging from minor to severe [4]. Looking back historically, from the emergence of the automobile to the present day, road traffic accidents involving automobiles have claimed between 60 and 80 million lives, while at least 2 billion people have sustained injuries [5].

Increased emissions of combustion products from vehicles directly contribute to a decline in the quality of life in urban areas [6,7]. During operation, automobiles emit harmful combustion products, including CO_2—carbon dioxide, NO_x—nitrogen oxides, PM—particulate matter, HC—hydrocarbons, CO—carbon monoxide, VOC—volatile organic compounds, and PAH—polycyclic aromatic hydrocarbons [8]. As the global population increases, so does the number of automobiles on the roads, contributing to premature mortality, particularly in urban areas and, especially, in low- and middle-income countries [9]. In 2023, as many as 7.9 million deaths worldwide were directly attributable to air pollution, making it the second leading risk factor for mortality globally [10]. Thus, air pollution ranks among the most significant contributors to premature mortality worldwide. Exposure to harmful substances emitted by vehicles can cause severe chronic respiratory and cardiovascular conditions, as well as premature death [11]. People living along heavily trafficked roads are not the only ones affected; populations in more distant areas may also be exposed, as winds can transport contaminated air far from the original emission source [12].

Vehicles affect not only humans but also flora and fauna. Plants growing alongside roads are among the first to be exposed to harmful vehicle emissions [13]. Vegetation in the immediate vicinity of roads is primarily exposed to harmful exhaust emissions. Air pollution along heavily trafficked roads can induce morphological and physiological changes in plants, primarily through reductions in leaf area and chlorophyll concentration [14]. High levels of air contamination, combined with intensive traffic flows, contribute to the desiccation of a significant proportion of forest ecosystems and individual trees [15]. Consequently, the degradation of vegetation cover along roadways and within urban areas further contributes to the deterioration of ambient air quality in cities [16]. Furthermore, when a sufficient number of individuals of a particular plant species die without replacement, this may contribute to forced migration [17] or even the complete extinction of certain animal species [18], thereby fundamentally destabilizing the balance of the entire ecosystem [19,20]. Finally, the direct negative impact of road traffic on fauna is also reflected in the high mortality rate of animals resulting from collisions with vehicles [21,22].

1.2. Traffic Congestion: From Economic Losses to Digitalization

In addition to health risks, the large number of automobiles generates chronic traffic congestion, particularly in densely populated urban areas [23]. Congestion most commonly occurs during peak traffic periods, when the number of vehicles using the road network exceeds its available capacity [24–26]. In addition to increased pollution [27] caused by engine idling, these conditions result in unnecessarily prolonged travel times and systematic delays in commuting to work [28]. The magnitude of this problem is evident: in 2024, commuters in 100 major cities across China lost an average of as many as 82 h due to traffic congestion [29]. Traffic congestion not only causes direct economic losses for travelers but also generates substantial social and environmental costs [30]. Furthermore, traffic congestion can contribute to the occurrence of road traffic accidents [31].

The solution to urban traffic constraints is not the expansion of road infrastructure [32], but rather the implementation of smart cyber–physical systems [33]. Intelligent transport systems (ITS) have become a key driver of this process within smart cities [34]. By integrating information and communication technologies (ICT), such as the Internet of Things (IoT), 5G/6G communication networks, edge computing, and artificial intelligence (AI), ITS transforms passive road infrastructure into dynamic, self-optimizing networks capable of real-time optimization through V2X (Vehicle-to-Everything) communication protocols [35,36].

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1.3. Outline and Objectives of the Review Paper

Although numerous studies have investigated intelligent transport systems (ITS), there is a clear lack of research that comprehensively integrates findings on how ITS can address road safety, harmful emissions, and travel time. The primary objective of this review paper is to provide an overview of the latest ICT-based ITS solutions and to analyze their impact on society. The structure of this review paper is organized into six sections. Section 1 defines the research problem and the motivation for conducting this study. Section 2 provides the methodology used to review studies in the relevant research area. Section 3 introduces the fundamental operating principles and the three-layer architecture of modern ITS. Section 4 represents the core of the research, analyzing the quantitative effects of ITS on road safety improvement (Section 4.1), emission reduction (Section 4.2), travel time optimization (Section 4.3), and traffic management (Section 4.4). Section 5 discusses the future development of intelligent transport systems through the integration of AI, IoT, 6G, edge computing, and big data analytics. It focuses on their potential to enable more efficient traffic management while simultaneously reducing emissions and travel time and improving road safety. Section 6 summarizes the key findings and provides concluding remarks.

2. Research Methodology

The research methodology is presented in Figure 1 and comprises several interconnected steps. The first step of the research involves a review of the available scientific literature from relevant databases and platforms, such as Scopus, IEEE Xplore, MDPI, Springer, and Google Scholar. The studies included in the further analysis are recent publications. Based on the analysis of relevant scientific studies, current topics and research areas in the field of intelligent transport systems (ITS) were identified, which served as the basis for defining the content and objectives of the research.

Following the definition of the research topic, the study focuses on presenting the fundamental concepts of intelligent transport systems, including basic terms and definitions, as well as the ITS architecture. This section provides the theoretical foundation necessary for understanding how intelligent transport systems operate, their components, and the interconnection between different subsystems.

In the next step, the key impacts of ITS implementation in transport were analyzed. Based on the previously conducted literature review, road safety, the reduction in harmful emissions, and travel time reduction were identified as particularly significant areas. This part of the study examines the potential of ITS to improve the safety of road users, optimize traffic flows, and reduce the negative impact of transport on the environment, as well as to increase the efficiency of the transport system and reduce travel time.

Based on the analyzed results and identified trends, future directions for development and potential research in the field of ITS are presented in the following section. Particular attention is given to the further development of intelligent technologies and their application to further improve road safety, reduce emissions, and increase traffic efficiency.

The final step involves formulating the conclusions, which are derived from the results of the review and analysis of the available literature. In this way, the proposed methodology connects the identification of current research areas with the theoretical foundations of ITS, the analysis of their most significant impacts, and the definition of potential directions for future development.

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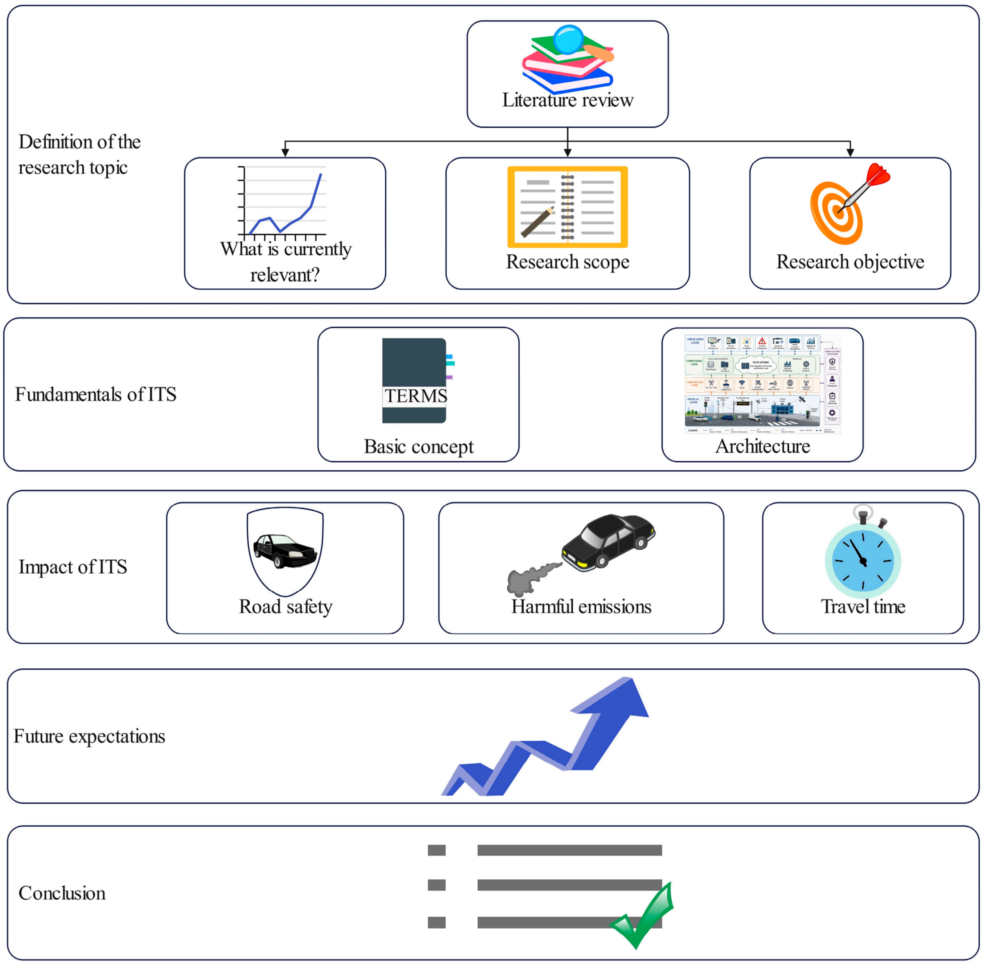

Figure 1. Research methodology.

3. Fundamentals and Architecture of Intelligent Transport Systems

Intelligent transport systems (ITS) represent a revolutionary integration of information and communication technologies and telecommunications technologies that fundamentally transforms the transportation of people and goods through advanced methods of transport implementation, operation, and management [37,38]. By integrating state-of-the-art infrastructure, sensor networks, real-time data, and intelligent algorithms, these systems optimize key aspects of transportation, including traffic flow management, vehicle operation, and public transport [39]. The primary objective of ITS implementation is to significantly improve the operational efficiency and overall effectiveness of the transport system by reducing traffic congestion and travel time, while simultaneously enhancing road safety and minimizing negative environmental impacts [38,40].

Figure 2 presents the architecture of an ITS based on the comprehensive V2X communication concept, which integrates vehicles, pedestrians, and road infrastructure into a unified digital network [41,42]. Through synchronized real-time data exchange, vehicles communicate with one another, with vulnerable road users, and with roadside units, while relying on global navigation satellite systems for accurate geolocation. All collected telemetry data from sensors are transmitted through advanced wireless and backhaul networks to centralized processing centers, where traffic flows are analyzed and dynamically optimized, thereby significantly enhancing overall safety in urban environments.

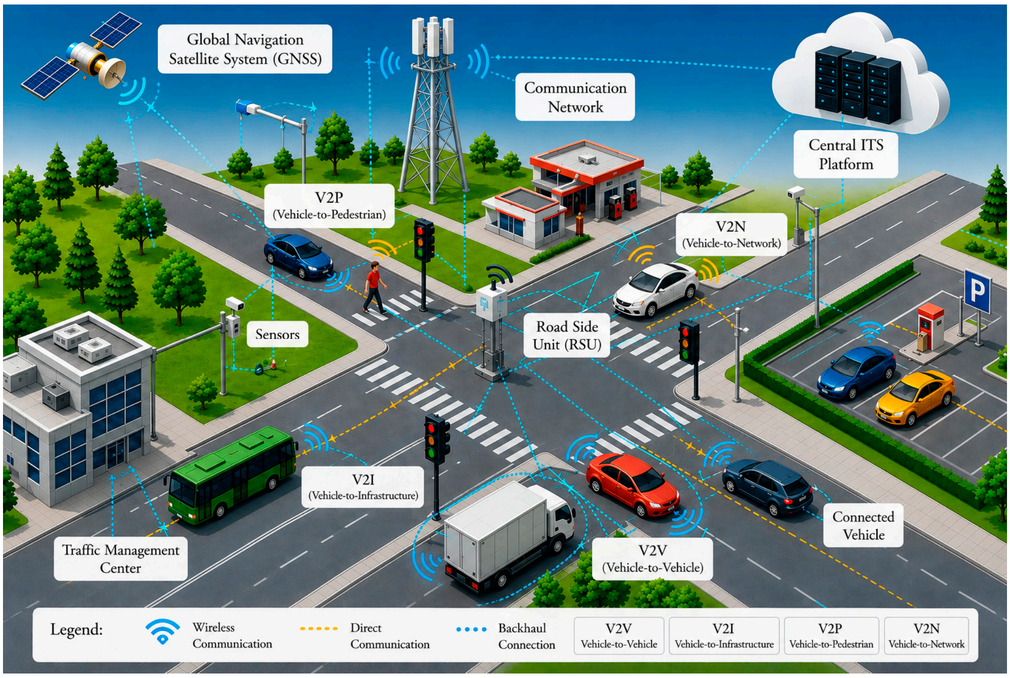

Figure 2. V2X communication. Source: Authors' own illustration based on the literature synthesis; visualization assisted by generative AI (2026).

3.1. The ITS Architecture

Modern ITS operates as a data-driven system. Its fundamental principle is based on a continuous loop [43]: detecting the current state of traffic, transmitting and processing large volumes of data, and implementing real-time control. To better understand its operation, the ITS architecture can be divided into four interconnected layers [44,45] (Figure 3):

1. First layer—physical layer;
2. Second layer—communication layer;
3. Third layer—computation layer;
4. Fourth layer—application layer.

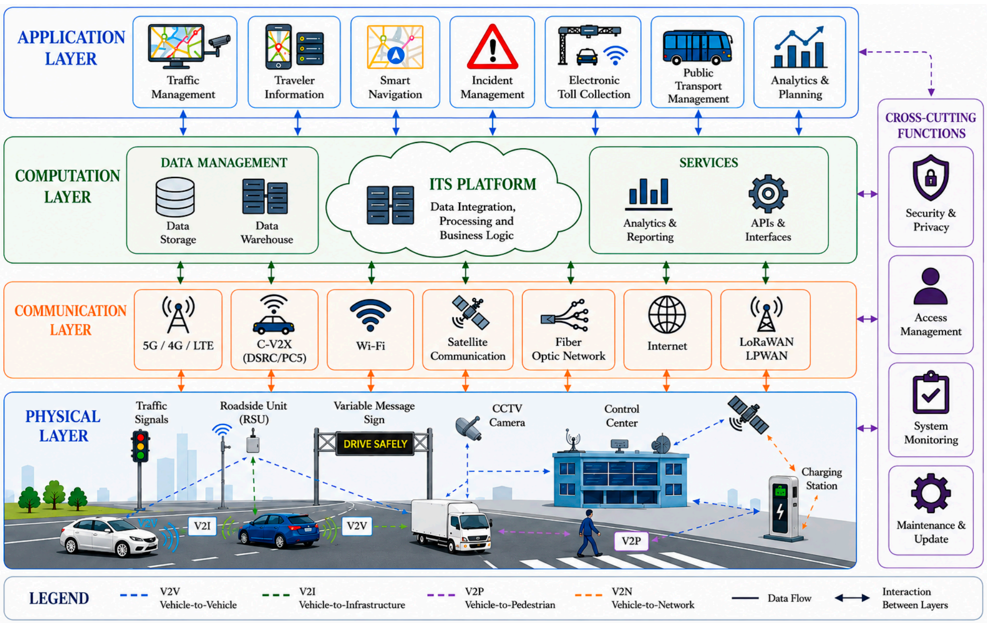

Figure 3. ITS architecture. Source: Authors' own illustration based on the literature synthesis; visualization assisted by generative AI (2026).

3.2. Physical Layer

Data collection represents the fundamental layer of the ITS architecture. It enables the acquisition of data in real time with a high degree of accuracy. Data can be collected from both stationary and mobile devices [46]. Stationary devices are those installed at fixed locations and include:

- Inductive loop detectors—sensors embedded in the road pavement and used for vehicle counting and speed measurement [47].
- Closed-circuit television (CCTV)—systems that serve as a source of spatial and temporal traffic data [48].
- LiDAR (Light Detection and Ranging) and radar—highly accurate systems for vehicle detection and classification. LiDAR generates a point cloud representing the detected vehicle and, together with radar, enables accurate determination of vehicle position, even under poor visibility conditions [49,50].

Unlike stationary devices, mobile devices cover a larger geographical area and may include:

- FCD (Floating Car Data)—collects real-time traffic data along a given route while the vehicle is located using a mobile phone or GPS [51,52].
- On-board vehicle sensors—on-board diagnostics, sensors, and cameras installed in the vehicle can provide telemetry data [53,54].

3.3. Communication and Computation Layer

Following data collection, the next step is data transmission. Data transmission is achieved through:

- Vehicle-to-Everything (V2X)—represents communication within a dynamic traffic environment, where the final letter indicates the entity with which the vehicle communicates. These communication models include [55–57]:
    - V2V (Vehicle-to-Vehicle) communication model—operates through wireless communication, enabling vehicles to exchange information about accidents and traffic congestion. Vehicles can also transmit information about their current speed and position, allowing them to respond more rapidly than a human driver [58].
    - V2I (Vehicle-to-Infrastructure) communication model—enables bidirectional wireless data exchange between vehicles and elements of the road infrastructure. This system integrates data from both traffic flows and various infrastructure components, including optical sensors, traffic light signalization, smart street lighting, speed limit monitoring systems, and weather stations [59].
    - V2N (Vehicle-to-Network) communication model—relies on cellular networks and dedicated short-range communication. In this model, the vehicle functions similarly to a mobile device, receiving information such as notifications about traffic accidents [60].
    - V2P (Vehicle-to-Pedestrian) communication model—establishes communication between vehicles and vulnerable road users, such as pedestrians and motorcyclists, with the aim of detecting, warning about, and preventing potential collisions. Data are exchanged in real time between smart devices used by vulnerable road users and sensors installed on vehicles [61].
    - 5G and 6G—these represent two key technologies from which significant advances are expected, namely fifth-generation broadband cellular networks (5G) and sixth-generation broadband cellular networks (6G) [62]. 5G enables connectivity anytime and anywhere [63]. The introduction of 5G has substantially

increased mobile data transmission speeds and reduced latency, while 6G is expected to enable near-instantaneous data transmission, exceptionally high reliability, and the seamless integration of the physical and virtual worlds [64].

The next step after data transmission is data processing. Data are processed in two main ways:

- Edge computing—based on local data processing [65] which is performed precisely where improvements in response time and bandwidth efficiency are required [66]. This approach enables real-time data analysis, which is particularly important in transportation, rather than transmitting data to a central processing facility for subsequent analysis [67].
- Cloud computing and big data analytics—cloud computing enables remote servers to store and process data [68]. These systems process data that are not time-sensitive [66], and use them for macro-level traffic optimization [69]. They can also be used to analyze historical traffic events. Such processing and learning from traffic-related events require substantial computational resources [70].

3.4. Application Layer

The application layer is the highest layer of the ITS architecture and provides users with a range of services. The network layer processes real-time vehicle data, which are subsequently delivered to the vehicle after processing [71]. In this way, users can access a range of travel-related services associated with their location and navigation. More specifically, these services support trip planning by enabling users to avoid traffic congestion and identify the fastest routes [41,72].

4. Impact of Intelligent Transport Systems on Key ASPECTS of Transportation

4.1. Enhancing Road Safety

The primary objective of implementing intelligent transport systems is to improve road safety and reduce the risk of loss of human life [73]. A significant area of ITS application is urban transportation, where these systems not only contribute to safer road traffic operations [74], but also enable a quantifiable reduction in the number of road traffic accidents and, consequently, mortality rates [75], while providing authorities with valuable information to support law enforcement [76]. For risk assessment, one of the commonly applied methodological approaches is bowtie analysis, which integrates expert assessments and existing scientific knowledge regarding the probability of road traffic accidents and the effectiveness of preventive measures [77]. On the other hand, when an accident has already occurred, ITS algorithms enable the dynamic determination of optimal emergency transport routes to hospitals, while minimizing the impact of traffic congestion and delays [78,79]. In addition to urban environments, these systems play a key role as an effective tool for improving road safety in regions characterized by extreme climatic conditions. For example, a specialized ITS implemented in the Arctic is designed to rapidly detect traffic accidents, predict potential scenarios, and determine optimal response strategies in emergency situations. This system operates by analyzing the consequences of accidents, thereby enabling the efficient allocation and rerouting of available rescue resources [80]. Table 1 provides a concise overview of the previously discussed studies, including the technologies and methodologies applied and the results obtained by the respective authors, while Figure 4 provides an illustrative representation of these findings.

Table 1. Summary of ITS technologies applied to improving road safety.

References	Applied Technology/Methodology	Results
[73]	Machine learning	Improved road safety and reduced risk of loss of human life.
[74]	Digital twins	Improved traffic efficiency and road safety.
[75]	Combined application of cognitive technologies in transportation	Reduction in the number of road traffic accidents, mitigation of their consequences, saving human lives, and protecting human health.
[76]	Image processing, intelligent algorithms (such as FaceMesh Model (Mediapipe)), Canny Edge Detection, and MobileNet), and an 8 GB Raspberry Pi 4 model B	Providing valuable information to authorities for law enforcement purposes.
[77]	Bowtie analysis	Prevention of road traffic accidents or mitigation of their consequences.
[78]	Numerical algorithms	Identification of the fastest route for transporting road traffic accident victims to a hospital.
[79]	Digital twins	
[80]	IDEF0 methodology	Rapid response of rescue services in regions with extreme climatic conditions.

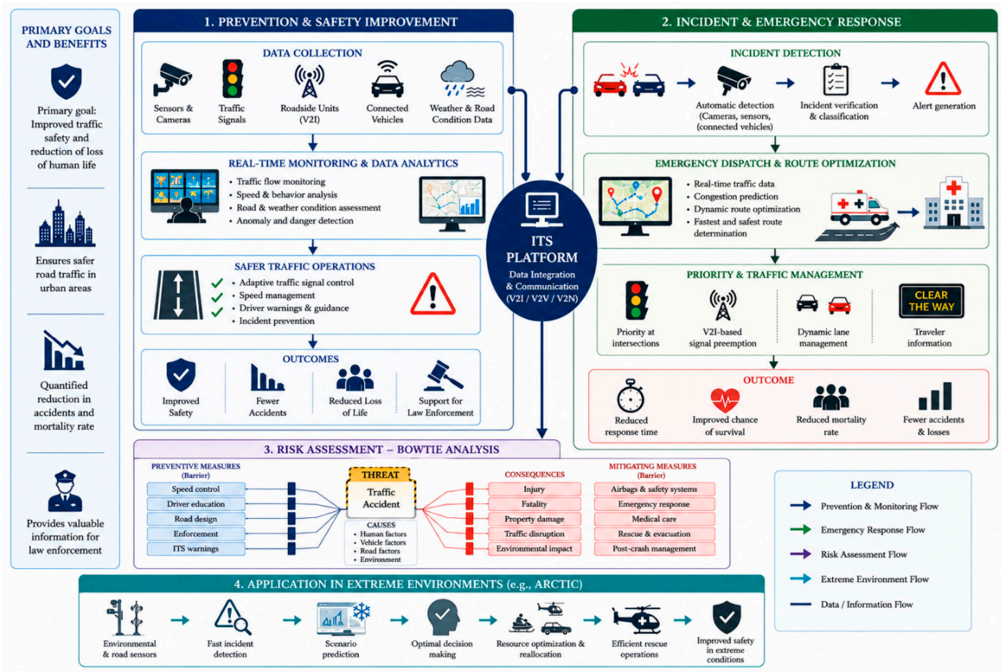

Figure 4. Illustrative summary of ITS applications for road safety. Source: Authors' own illustration based on the literature synthesis; visualization assisted by generative AI (2026).

4.2. Emission Reduction

High traffic flow intensity generates traffic congestion, which directly contributes to increased carbon emissions [81]. Under such conditions, a large number of vehicles operate at idle. Within the contemporary concept of smart cities, transport systems are subject to stringent requirements aimed at reducing harmful emissions and improving the overall quality of life in urban areas [82]. Since the transport sector represents one of the three leading global sources of carbon emissions [83] (Figure 5), the implementation of ITS has emerged as a key solution for achieving energy efficiency and reducing the environmental footprint of transportation networks [84,85]. The highest share of energy consumption occurs in urban transportation, where challenges arise in the areas of management, regulation, spatial planning, control mechanisms, and applied technologies [86]. The implementation of ITS can significantly reduce carbon emissions per kilometer traveled, primarily by shortening travel times and enabling route changes during a trip compared with the initially selected route [87]. This can be effectively achieved through the integration of advanced traffic flow prediction models; the proposed predictive model quantifies expected exhaust emissions and fuel consumption based on road network conditions, generating the most environmentally and time-efficient route as the output [88,89]. Accordingly, continuous monitoring of traffic indicators, such as congestion levels, enables timely rerouting to road sections with lower levels of saturation, thereby further minimizing energy consumption and reducing emissions of combustion products [90,91]. Another approach to reducing emissions involves Intelligent Transportation Speed Guidance Systems (ITSGS), which promote lower average speeds and smoother driving patterns [92]. In addition, dynamic traffic management enables the control of vehicle speed and acceleration through V2I connectivity, with the aim of reducing emissions [93].

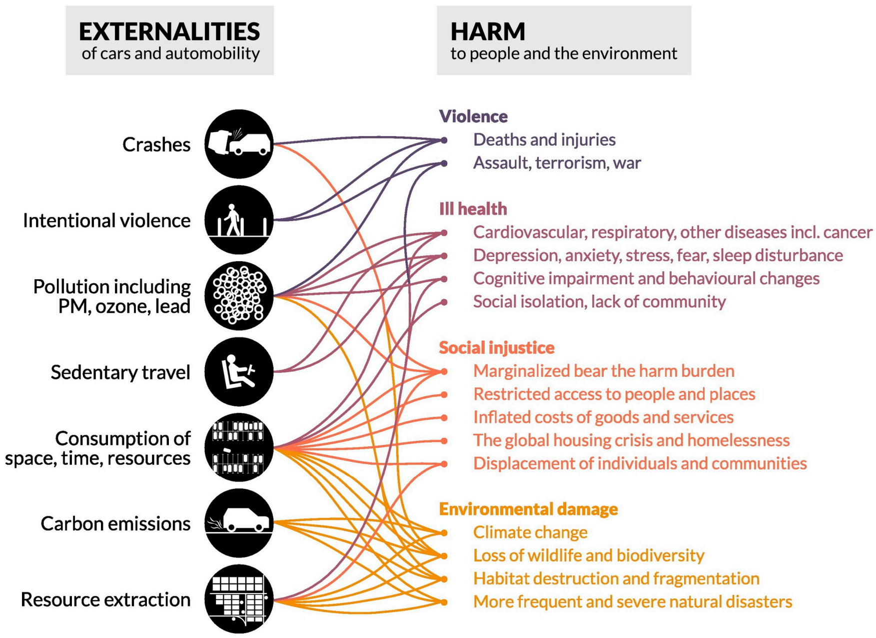

Figure 5. Unforeseen consequences of automobile use and their impact on humans and the environment [5].

When discussing emissions originating from vehicles, this does not refer solely to emissions generated by internal combustion engine operation, but also to noise produced by vehicle operation. Thus, in addition to harmful emissions from internal combustion engines, urban areas are also affected by traffic noise [94]. Vehicle routing is generally performed primarily to avoid traffic congestion, while noise is often neglected. However, some systems not only provide the best available routes but also display the noise levels along these road sections in real time. The optimal route is determined based on two criteria: physical capacity and acoustic capacity [95]. Vehicle-related noise is generated not only by internal combustion engine operation but also by the use of horns, particularly when traffic congestion occurs [96].

A brief overview of the reviewed studies, including their research topics and concise summaries of the findings, is presented in Table 2, while Figure 6 provides an illustrative representation.

Table 2. Summary of research areas/topics with a brief overview of ITS applications for emission reduction.

References	Research Area/Topic	Brief Summary
[81]	Traffic congestion and emissions	High traffic intensity leads to congestion, vehicle idling, and increased carbon emissions.
[82]	Smart city requirements	Modern transportation systems must reduce harmful gas emissions and contribute to improving the quality of life in urban areas.
[83]	The role of transportation in emissions	Transportation represents one of the three leading global sources of carbon emissions, making improvements in transport energy efficiency highly important.
[84,85]	ITS as a solution	The implementation of intelligent transport systems (ITS) enables more efficient traffic management, reduced energy consumption, and a lower environmental footprint.
[86]	Urban transportation challenges	The highest energy consumption occurs in urban transportation, accompanied by challenges related to management, regulation, spatial planning, control, and technology implementation.
[87]	Route optimization	ITS can reduce emissions per kilometer traveled by shortening travel time and dynamically changing routes during a journey.
[88,89]	Predictive models	Advanced traffic flow prediction models can estimate exhaust emissions and fuel consumption and propose an environmentally and time-efficient route.
[90,91]	Real-time traffic monitoring	Continuous monitoring of congestion levels enables timely rerouting of vehicles to less congested road sections, thereby reducing fuel consumption and emissions.
[92]	ITSGS	ITSGS contributes to emission reduction by optimizing average speed and promoting smoother driving patterns.
[93]	V2I and dynamic traffic management	Dynamic traffic management and V2I communication enable the control of speed and acceleration of connected vehicles to reduce emissions.
[94]	Noise as a form of pollution	The impact of transportation is not limited to exhaust emissions; vehicles also represent a significant source of noise in urban areas.
[95]	Noise-aware routing	Modern routing systems can display not only traffic conditions but also noise levels along individual road sections in real time.
[96]	Sources of vehicle noise	Noise originates from engine operation as well as from the use of vehicle horns, particularly during traffic congestion.
[95]	Route selection criteria	The optimal route can be determined based on the physical capacity of the road and its acoustic capacity, i.e., noise level.
[88–96]	Integrated approach	By combining data on congestion, emissions, fuel consumption, and noise, it is possible to define an environmentally, time-, and acoustically optimal route.

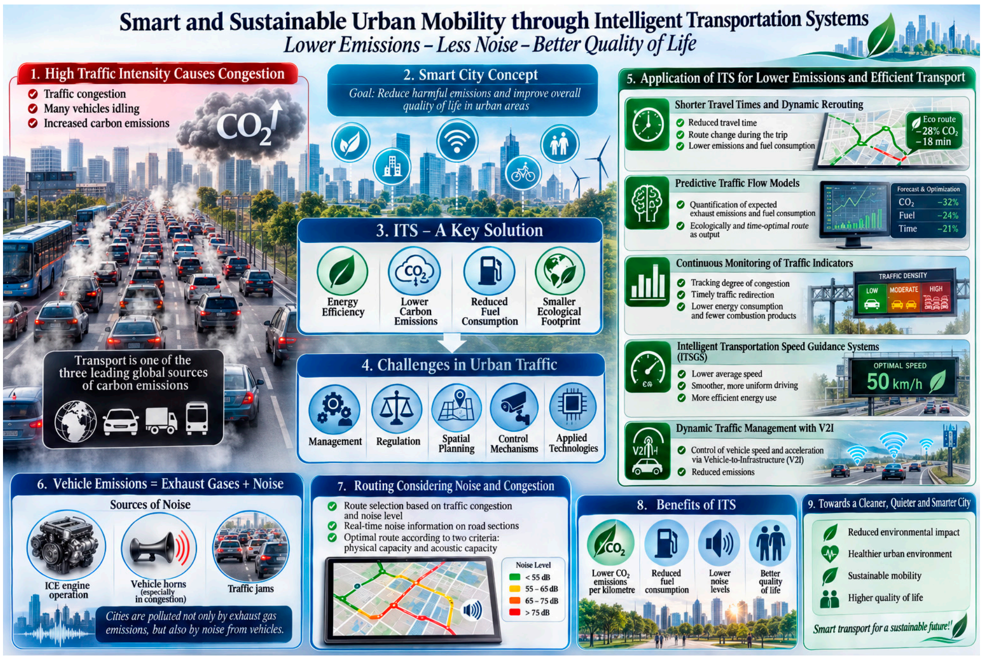

Figure 6. Illustrative summary of ITS applications for emission reduction. Source: Authors' own illustration based on the literature synthesis; visualization assisted by generative AI (2026).

4.3. Traveling Time Reduction

The application of intelligent transport systems enables improved traffic coordination and planning, with the aim of avoiding congestion and ensuring timely arrival at the desired destination [97], as well as optimizing traffic signal control [98]. To address the challenges arising in highly mobile urban environments, the implementation of intelligent transport systems enables the dynamic evaluation of traffic conditions in real time [99]. The operation of a transportation system is closely related to the processing of fundamental traffic data [100]. To achieve this, the prediction of various traffic parameters represents one of the most important steps [101,102]. Traditional models exhibit significant limitations in capturing temporal dependencies, global information, and nonlinear relationships that are essential for traffic flow analysis, thereby limiting their optimization performance. To overcome these challenges, Mamba-ATSP [103], as well as digital twins have been introduced [104]. In addition, the Intelligent Adaptive Traffic Control and Management System (IATCMS) can be applied at intersections worldwide, enabling smoother traffic flow and helping to prevent congestion [105]. In addition to ensuring timely arrival at work, timely response is particularly important in the provision of emergency medical services [106]. In this context, ITS plays a crucial role in identifying faster routes, enabling emergency services to use the fastest routes to accident locations and supporting traffic management before congestion occurs [107]. Furthermore, ITS enables faster arrival at accident locations, reducing travel time by 9% [108], as traffic signals can be adapted to give priority to emergency vehicles and allow them to pass without interruption [109]. It is also essential to prevent false alarms indicating that a traffic accident has occurred, which has been addressed through the MDTS-ADNet algorithm [110]. Artificial intelligence and deep learning are increasingly being applied to enable the analysis and visualization of traffic accident data, accident prevention, and the evaluation of safety improvement strategies, thereby supporting highway administrative and engineering authorities in more effectively minimizing the frequency and severity of traffic accidents [111]. Figure 7 provides an illustrative representation of the findings discussed above.

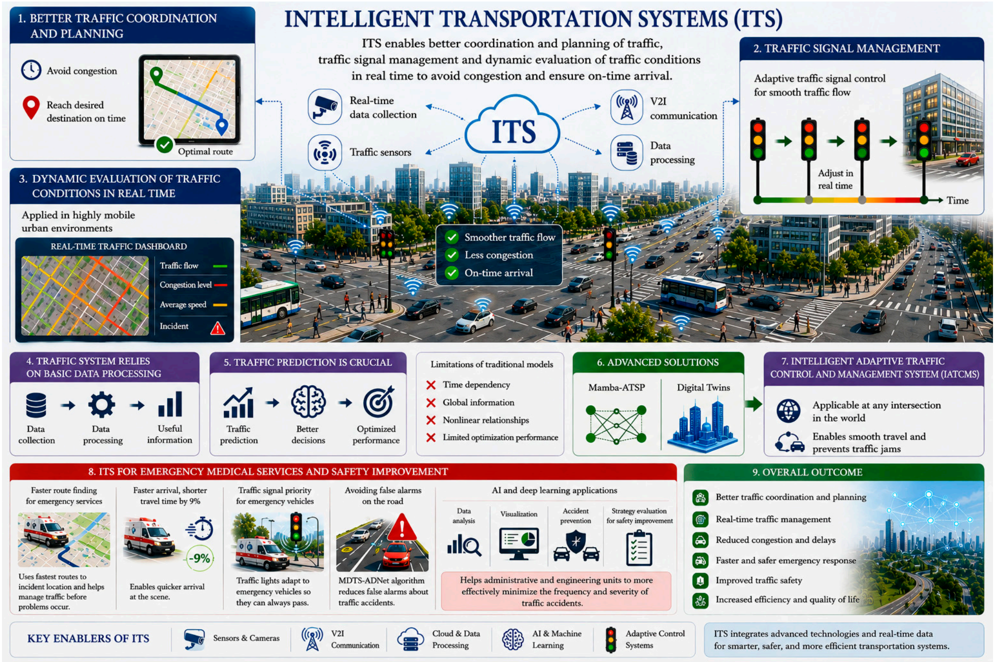

Figure 7. Illustrative summary of ITS applications for travel time reduction. Source: Authors' own illustration based on the literature synthesis; visualization assisted by generative AI (2026).

4.4. Theoretical Traffic Management from the Perspective of Safety, Energy Efficiency, and Environmental Quality

The first three sections of this chapter present a review of research in the relevant field, while this section integrates all the findings into a single algorithm, which was derived based on the review of the literature presented in the previous three subsections. The proposed theoretical algorithm represents a traffic management framework from the perspectives of safety, energy efficiency, and environmental quality.

The proposed theoretical algorithm (Figure 8) represents an integrated framework for intelligent traffic management, combining data collection and processing, traffic state assessment and prediction, travel optimization, emissions and noise management, and road safety enhancement. The theoretical algorithm operates as a closed-loop system in which the state of the traffic network is continuously monitored and updated based on newly acquired data.

In the first phase, real-time data are collected from traffic sensors, cameras, GPS systems, traffic signals, and V2I communication, including information on traffic accidents, emergency vehicles, fuel consumption, harmful combustion emissions, and noise levels. Following data integration and processing, the current traffic conditions are assessed, including traffic volume, speed, congestion level, travel time, harmful combustion emissions, and noise levels.

The next step involves predicting the future state of the traffic network, based on which potential congestion or an increased risk of its occurrence is identified. If intervention is deemed necessary, dynamic traffic optimization measures are activated, such as route changes, traffic signal control, speed management, and V2I-based control.

A specific component of the theoretical algorithm focuses on multi-criteria route optimization, in which, in addition to travel time and congestion levels, fuel consumption, harmful combustion emissions, and traffic noise levels can also be considered. In the presence of an emergency vehicle, the algorithm determines the fastest route and activates priority traffic signal control, thereby enabling faster passage and reducing response time.

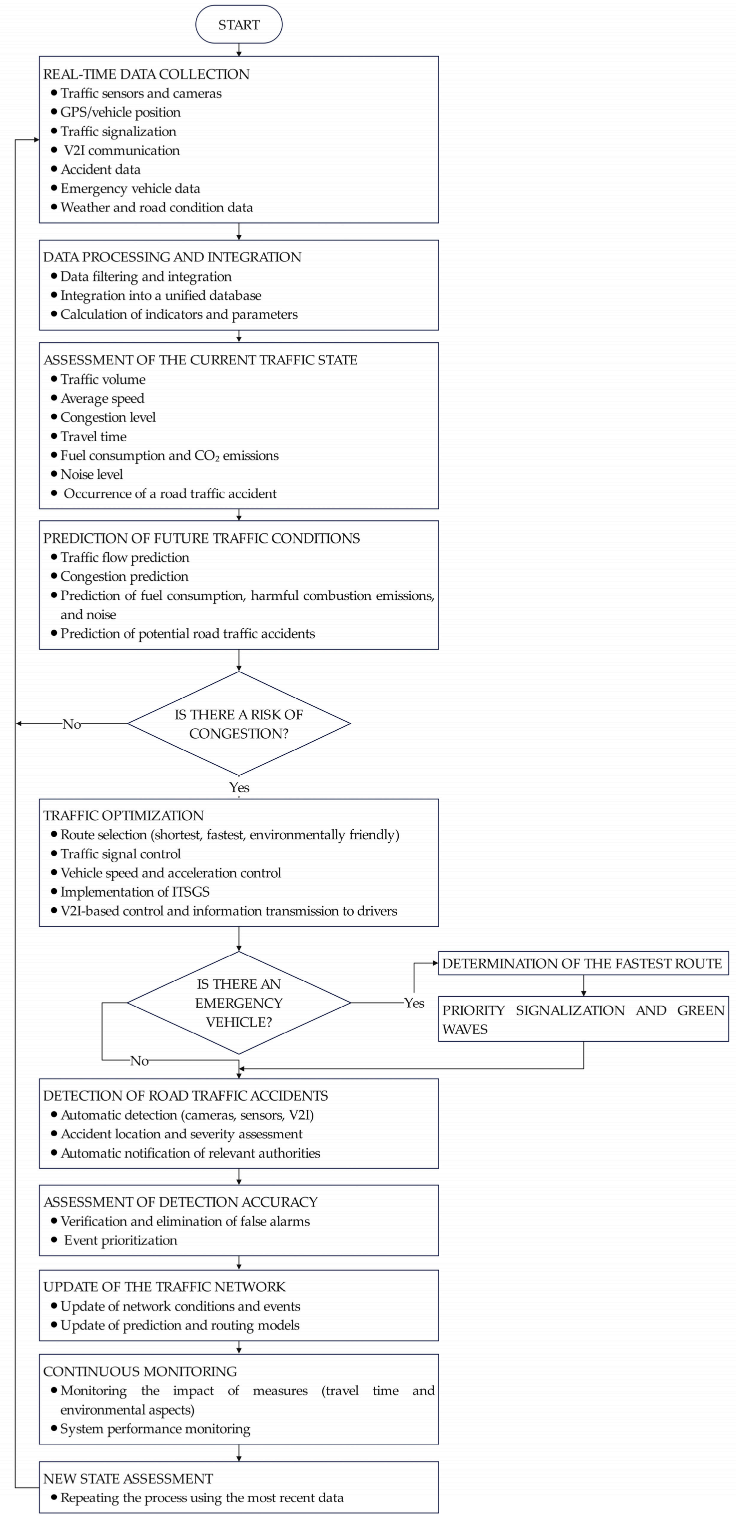

Figure 8. Theoretical traffic management algorithm from the perspective of safety, energy efficiency, and environmental quality.

In parallel, continuous detection and verification of traffic accidents are performed, after which the state of the traffic network and the prediction and routing models are updated. Finally, the effects of the implemented measures are evaluated using indicators such as travel time, congestion, energy consumption, harmful combustion emissions, noise, and road safety, with the obtained results being used for a new assessment of the traffic state.

In this way, the theoretical algorithm establishes a continuous feedback loop between monitoring, prediction, decision-making, and control, enabling the dynamic adaptation of the transportation system to changing real-time conditions.

5. Future Expectations for Intelligent Transport Systems

Intelligent transport systems emerged from the need to reduce traffic congestion and improve urban mobility. Advances in artificial intelligence, particularly through the application of multi-agent systems, deep Q-networks, and adaptive traffic signal control based on artificial neural networks, together with Internet of Things (IoT) connectivity and big data analytics, have enabled significant improvements in traffic flow management [112,113]. These technologies enable dynamic adaptation to current traffic conditions, thereby effectively reducing congestion. Future intelligent transport systems are expected to ensure seamless cooperation between existing and emerging technologies. Research investigating the integration of Internet of Things (IoT), Sixth-Generation (6G) mobile communications technology, and Artificial Intelligence (AI) indicates the potential for developing smarter and more highly connected intelligent transport systems [114,115].

A defining characteristic of contemporary transportation is the large number of vehicles and the countless traffic scenarios that occur at any given moment. To enable the transmission of large volumes of data, 6G networks have emerged as a promising solution [116], while artificial intelligence is capable of analyzing vast amounts of data and real-time events [117]. This enables more effective detection of potential threats or abnormal activities before they lead to disruptions in ITS operation. At the same time, 6G enables faster and more efficient real-time data transmission in the event of a road accident [118], allowing vehicles to slow down and thereby avoid becoming involved in subsequent collisions [119,120]. In addition, edge computing can process data closer to its source, reducing latency and bandwidth consumption by processing data locally before transmitting it to the cloud [121]. The future implementation of these technologies will facilitate traffic data collection and support more accurate decision-making [99]. Accordingly, future ITS are expected to focus on monitoring large volumes of data and processing them more rapidly and reliably, with the aim of reducing emissions and travel time while maintaining a high level of road safety. Figure 9 provides an illustrative representation of the future development of ITS based on the research findings discussed in this chapter.

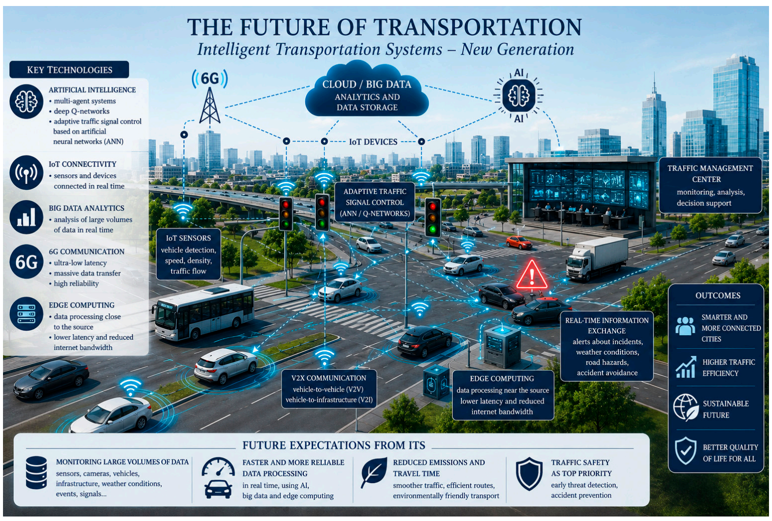

Figure 9. The future of ITS. Source: Authors' own illustration based on the literature synthesis; visualization assisted by generative AI (2026).

6. Conclusions

The intensive development of road transportation and the increasing degree of urbanization have led to increasingly pronounced challenges related to road safety, traffic congestion, travel time, energy consumption, and the negative environmental impacts of transportation. In this context, intelligent transport systems (ITS) represent a significant direction in the development of modern transportation, as the integration of sensor systems, information and communication technologies, V2X communication, artificial intelligence, and advanced data processing methods enables dynamic traffic flow management. The aim of this paper was to systematize the contemporary possibilities for applying ITS to improve road safety, reduce emissions, and shorten travel time, as well as to integrate these aspects into a unified approach to traffic management. Based on the analyzed literature, the following key conclusions can be drawn:

- ITS enable a transition from traditional to dynamic and predictive traffic management based on the continuous collection, transmission, and processing of real-time data.
- The application of ITS contributes to improved road safety through the early detection of hazardous situations, risk prediction, intelligent traffic flow management, and more efficient responses to road traffic accidents.
- ITS can contribute to reducing energy consumption and harmful combustion emissions through traffic flow optimization, dynamic routing, congestion reduction, and smoother driving patterns. At the same time, route optimization can also incorporate traffic noise levels as an additional criterion.
- Travel time reduction can be achieved through dynamic assessment of the traffic network, prediction of its future state, and adaptation of routes and traffic signal control to current conditions. This approach is particularly important for the management of emergency vehicles, where route optimization and traffic signal prioritization can contribute to faster emergency response.
- The most significant contribution of this study is the integration of the aforementioned aspects into a unified conceptual traffic management algorithm. The proposed algorithm combines data collection and processing, traffic state assessment and prediction, route optimization, emissions and noise management, and road safety enhancement. Its closed feedback loop enables continuous monitoring of the effects of implemented measures and their adaptation to changing conditions within the traffic network.

Based on the above findings, it can be concluded that the future of intelligent transport systems lies in the integration of different technologies and their coordinated operation. Artificial intelligence, IoT, 6G communication networks, and edge computing have particular potential to enable faster data processing, more reliable prediction, and more efficient real-time decision-making. Future research should focus on the experimental and simulation-based validation of the proposed algorithm using real-world traffic data, together with the application of multi-criteria optimization methods that simultaneously consider safety, travel time, energy consumption, emissions, and noise. In addition, further research should investigate the integration of AI, IoT, 6G, and edge computing technologies into a unified ITS platform, as well as their interoperability with existing transportation infrastructure.

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Abbreviations

The following abbreviations are used in this manuscript:

ITS	Intelligent Transport Systems
V2X	Vehicle-to-Everything
IoT	Internet of Things
AI	Artificial intelligence
CO_2	Carbon dioxide
NOx	Nitrogen oxides
PM	Particulate matter
HC	Hydrocarbons
CO	Carbon monoxide
VOC	Volatile organic compounds
PAH	Polycyclic aromatic hydrocarbons
ICT	Information and communication technology
5G	Fifth-generation
6G	Sixth-generation
CCTV	Closed-circuit television
LiDAR	Light Detection and Ranging
FCD	Floating Car Data
V2V	Vehicle-to-Vehicle
V2I	Vehicle-to-Infrastructure
V2N	Vehicle-to-Network
V2P	Vehicle-to-Pedestrian
ITSGS	Intelligent Transportation Speed Guidance Systems
IATCMS	Intelligent Adaptive Traffic Control and Management System

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