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AI-Enhanced Route Optimization Algorithms: A Survey on Intelligent Transportation Systems

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Abstract: *India, possessing the world's second-largest road network, continues to experience frequent and fatal road accidents, emphasizing the critical need for effective traffic monitoring and route optimization. In order to increase road safety, alleviate traffic, and control traffic, modern technologies like cloud computing, artificial intelligence (AI), the Internet of Things (IoT), and real-time data analytics have been combined to create Intelligent Transportation Systems (ITS), which have revolutionized the industry. This paper investigates the foundational concepts of route optimization in ITS, the enabling communication technologies such as V2X, DSRC, and C-V2X, and the architecture of ITS data ecosystems. A key component of dynamic route planning is the integration of AI through machine learning (ML), deep learning (DL), reinforcement learning, swarm intelligence, traffic signal optimization, and predictive maintenance. Furthermore, the paper reviews key AI-based methodologies, real-world case studies, and emerging techniques aimed at improving efficiency, safety, and sustainability in transportation. The paper concludes by highlighting ongoing advancements and identifying future directions for research in AI-driven ITS frameworks.*

Keywords: Intelligent Transportation Systems (ITS), Route Optimization, V2X Communication, DSRC, C-V2X, Traffic Management

I. INTRODUCTION

India possesses the second-largest road network globally, and consequently, road accidents are frequent and claim numerous lives annually. Identifying the root causes of such accidents is essential to developing effective preventive measures. In recent years, collecting traffic data has become a critical component of transportation forecasting, involving significant investments in terms of value and workforce. Traffic data are often segmented into regimes, such as free-flow and congested-flow conditions, to identify patterns and breakpoints in traffic behavior. In two-regime traffic models, dominant control strategies are used to distinguish between uncongested and saturated traffic states [1]. Traffic congestion, which results in substantial losses of time and energy, arises when traffic demand approaches or exceeds the network's service capacity.

Fortunately, the proliferation of systematic sensor deployments including CCTV cameras, GPS devices, and other IoT-based sensors across major metropolitan areas has led to the accessibility of enormous volumes of current and historical traffic data with superior geographic and temporal resolution [2]. This data proliferation has empowered Intelligent Transportation Systems (ITS) are being created to integrate state-of-the-art communication technologies to enhance the sustainability, security, and efficiency of contemporary transportation systems, real-time analytics, and intelligent algorithms. ITS focuses on improving multiple transportation facets such as traffic control, vehicle operation, and public transit by leveraging continuous sensor inputs and communication infrastructure.

A core challenge within ITS is traffic flow forecasting and route optimization, which are critical in mitigating congestion and enhancing mobility. Identifying the most effective route under a set of restrictions not just the shortest distance while taking delivery window considerations into account is the goal of route optimization., road type, queuing delays, fuel costs, construction, traffic signage, and environmental impact [3][4]. Route selection behavior is influenced by both static parameters (e.g., road infrastructure) and dynamic ones (e.g., real-time traffic and weather conditions).

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Optimization approaches can thus be divided into static and dynamic models, depending on whether travel costs remain constant or change over time.

The integration of Artificial Intelligence (AI) into route optimization has significantly advanced the field by enabling adaptive and data-driven decision-making. AI-driven route optimization algorithms utilize machine learning(ML), deep learning(DL), heuristic methods, and reinforcement learning techniques to analyze vast multimodal datasets, including traffic feeds, GPS logs, IoT sensors, and weather reports [5]. These algorithms enable continuous evaluation and adjustment of routes in real-time, offering tangible benefits such as cost reduction, increased delivery efficiency, enhanced safety, and minimized environmental impact. As urbanization and traffic volumes rise, AI-enhanced route optimization forms a pivotal component of intelligent and resilient transportation systems.

A. Structure of the paper

The paper is structured as follows: Section I introduces Intelligent Transportation Systems (ITS). Section II explains ITS foundations. Section III discusses communication technologies and route optimization. Section IV explores AI integration. Section V addresses challenges, Section VI reviews literature, and Section VII concludes with future research directions.

II. FOUNDATIONS OF INTELLIGENT TRANSPORTATION SYSTEMS (ITS)

A conglomeration of state-of-the-art information technology, communications, and electrical systems with the overarching goal of improving transportation efficiency and safety is known as an Intelligent Transport System (ITS). The three primary pillars of basic ITS technology are integration, information, and communication. The fundamental tasks of ITS include information acquisition (collection), processing, integration, and sorting. Individual passengers, drivers, carriers, and authorities become better informed and able to make "smart" decisions thanks to the ITS technologies [6]. The user services that ITS applications are anticipated to provide, the resources that support these services, and a planned architecture should outline how information and data move between the services and these resources. Simplified, it explains what it does, where it operates, and what data is shared among its parts. The tasks that ITS provides are referred to as user services. These activities include tracking commercial fleets, controlling traffic, electronically collecting fares, providing travel information, and recording traffic accidents. Figure 1 provides a detailed view of the ITS physical design.

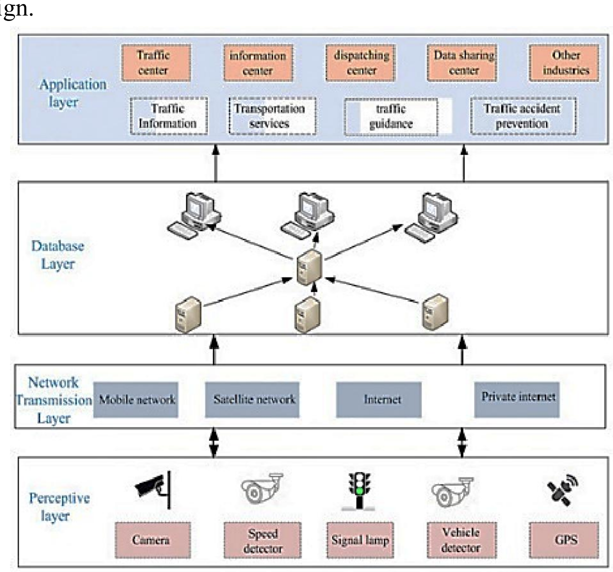

Figure 1: ITS Physical Architecture

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To handle the whole data lifecycle, Intelligent Transportation platforms (ITS) use a layer-based design for their big data platforms [7]. These devices also act as a source of data for intelligent cars that gather traffic data in the future. Examples of ITS using GPS systems are shown in Figure 2 below.

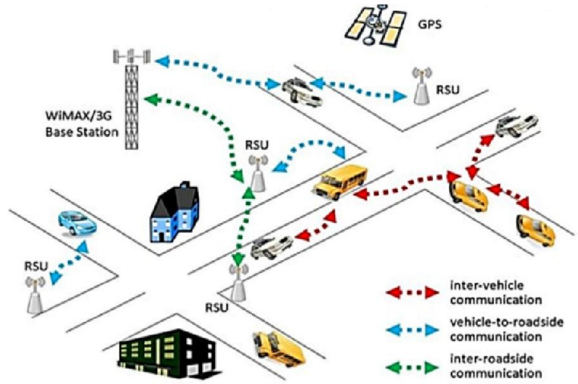

Figure 2: ITS Example with GPS

Perceptive Layer: This layer includes devices like cameras, speed detectors, vehicle detectors, signal lamps, and GPS. It collects real-time traffic data from the environment, enabling accurate monitoring of road conditions, vehicle movement, and traffic violations to support informed decision-making in the higher layers.

Network Transmission Layer: It transmits data from sensors using mobile networks, satellite links, the internet, and private intranets. This layer ensures continuous, secure, and real-time communication between field devices and backend systems for timely data processing and response.

Database Layer: Network data is processed, stored, and managed by this layer. It uses interconnected servers to organize and back up traffic information, ensuring reliable data access and synchronization across all ITS services and modules.

Application Layer: Traffic updates and other user services are provided by the application layer, transportation management, and accident prevention. It integrates traffic centers, dispatching units, and external industries, determining how services are delivered and which parts of the system are managed.

III. COMMUNICATION TECHNOLOGIES IN ITS FOR-ROUTE OPTIMIZATION

Communication technologies are essential for route optimization since they allow for dynamic modifications, real-time data transmission, and increased efficiency. These technologies, such as GPS, IoT, and telematics, allow for the gathering and examination of information that may be utilized to design the best routes, reduce delays, and improve customer satisfaction.

A. Route Optimization

A route is more than simply a trail or track when it comes to transportation and navigation; it's the vital link that joins two different sites and serves as an essential conduit for movement. According to, a route is a well-planned path that covers the distance between an origin and a destination, whether it is preset or feasible. This connection between places emphasizes how important it is to have a workable and practical route that allows for smooth movement [8]. In the domains of logistics, transportation, and network optimization, routing difficulties like the TSP and the VRP are two significant challenges. To accommodate a number of constraints, including reducing trip time, cost, or distance, these challenges entail determining the most effective routes for cars or people to visit a collection of sites. Efficiently resolving routing difficulties is essential for increasing overall productivity, cutting operating expenses, and optimizing resource allocation in many real-world applications. The following routing difficulties are discussed below:

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Vehicle Routing Problem (VRP)

In the complex optimization problem known as the VRP, a fleet of vehicles departs the central depot in order to best satisfy the needs of several clients at various locations, each of which has a shipping requirement. Finding the best course of action to lower total expenditures is the usual objective of a VRP.[9]. In order to minimize the overall expenses of the route, it is also necessary to take into account a number of elements that impact route design, such as fuel usage, vehicle capacity, traffic congestion, etc.

Travelling Salesman Problem (TSP)

The Travelling Salesman Problem (TSP) requires figuring out a salesman's route from a starting point, visiting a predetermined number of towns, and returning to the beginning point in a way that guarantees that every city is visited exactly once and reduces the total distance travelled. However, the TSP in its generality reflects a classic 'hard' combinatorial optimization issue, even though the route planning for a modern traveling salesman's business journey might not appear difficult.

B. Intelligent Transportation Communication Technologies

The integration of these systems is made possible by ITS communication technology. Information received from the vehicle cannot be sent to the centre via the Road Side Unit (RSU) equipment on the roadside. The AV and other nearby road users can share real-time information thanks to a technological paradigm known as V2X (Vehicle-to-Everything) connectivity. Figure 1 illustrates how Vehicle-to-Pedestrian (V2P), Vehicle-to-Infrastructure (V2I), and Vehicle-to-Vehicle (V2V) serve as an umbrella term that facilitates communication with various VRUs. A vehicle's communication with every other entity in its immediate surroundings is referred to as V2X. This includes both dynamic factors like other cars, pedestrians, and bicycles as well as static ones like road signs, traffic lights, and markings. In Figure 3, ITS communication technologies are displayed for each piece of equipment.

- Vehicle-to-Vehicle (V2V) Communication: permits direct communication between automobiles to improve traffic flow and safety.
- Vehicle-to-Infrastructure (V2I) Communication: makes it easier for cars and road infrastructure to communicate for better traffic control.
- Vehicle-to-Pedestrian (V2P) Communication: Improves safety by facilitating direct communication between cars and pedestrians.
- Vehicle-to-Network (V2N) Communication: enhances traffic management by connecting automobiles to external networks for real-time data transmission.

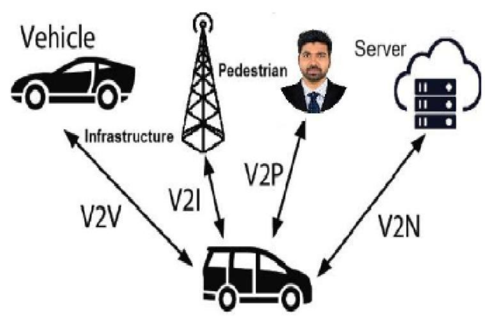

Figure 3: ITS Communication Technologies

C. Dedicated Short Range Communication (DSRC)

The 5.9 GHz DSRC wireless interface is expected to provide short-range, high-speed wireless communication between surface transportation infrastructure and automobiles. Additionally, it makes it easier for roadside equipment (RSE) and on-board equipment (OBE) to quickly share vehicle data and other material. Vehicles in a V2V communication environment are relatively mobile, and network topology changes often. [10][11]. Even when they are travelling in the same direction, cars' high relative speeds are the cause of these shifts. Only when two cars are within radio range of one another can they speak directly. The increased road vehicle mobility in DSRC may have two negative consequences on message sending and receiving performance for safety communication [12] The following metrics, which are shown in Figure 4, are defined to describe the performance of DSRC:

- **Packet Delivery Ratio (PDR):** The proportion of transmission efforts that result in successful communication events between two DSRC units at a specific distance.
- **Maximum Range (MR):** A vehicle or RSE can receive packets from another vehicle over a maximum distance of more than zero if the packet delivery ratio is large.
- **Effective Range (ER):** The period of time in which other vehicles whose packet delivery ratio exceeds a specific threshold (such as 50%) can send packets to the vehicle or RSE.

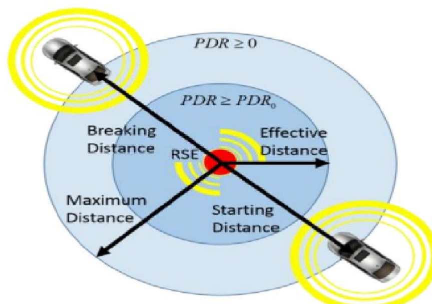

Figure 4: Maximum Range and Effective Range of DSRC Communication

D. Cellular Vehicle-to-Everything (C-V2X)

The widely used communication technology known as cellular vehicle-to-everything (C-V2X), which is based on time division long-term evolution (TD-LTE), is also occasionally referred to as LTE-V2X. 4G cellular technology, is intended to improve road safety and vehicle connection. 3GPP created it as a substitute for DSRC.

- C-V2X creates a full V2X ecosystem by enabling reliable and direct wireless communication between automobiles (V2V), between vehicles and infrastructure (V2I), and even with pedestrians and other road users who are more susceptible (V2P) [13]. Through low-latency, high-throughput data interchange made possible by this technology, which makes use of the current cellular network infrastructure, cars may transmit vital information including traffic conditions, emergency alerts, and real-time sensor data. C-V2X is leading the way in connected car and smart transportation research and development because of its tremendous potential to improve intelligent transportation systems, lower traffic accidents, and pave the way for future applications of autonomous driving.
- Since C-V2X is thought to be 802.11p's most potent rival, several studies have looked at how well they function in comparison. Link-level comparison revealed that C-V2X might increase the link budget by around 7 dB over IEEE 802.11p. Furthermore, with the same velocity, the study discovered that LTE V2X had a wider reach than DSRC. Additionally, LTE V2X's modulation approach makes it less vulnerable to noise, ensuring a more dependable communication channel than DSR.

IV. INTEGRATION OF AI IN INTELLIGENT TRANSPORTATION SYSTEMS

The majority of major cities worldwide deal with transportation, traffic, and logistical problems. This is brought on by both the rapidly expanding human population and the rise in the number of automobiles on the road. With technology, a sustainable transport system may be created and run considerably more effectively. Due to urban traffic congestion, artificial intelligence (AI) systems that combine real-time vehicle data for traffic management and mobility on demand for trip planning have surfaced. These systems use a single user interface. Additional possibilities for efficient traffic control include the secure integration of AI-based decision-making, routing, transportation network services, and other mobility optimization technologies. The World Economic Forum says artificial intelligence is a developing technology.

Among the AI methods used in transportation are the Ant Colony Optimizer (ACO), Fuzzy Logic Model (FLM), Genetic Algorithms (GA), Simulated Annealing (SA), and Artificial Neural Networks (ANN). Reducing traffic, improving commuters' journey times, and enhancing the system's overall economy and productivity are the goals of implementing these strategies in transportation management [14].

A. Integration of AI in Route Optimization

The next section discusses how AI and ML have become effective techniques for tackling transport route optimization problems. Large datasets may now be analyzed because of these technologies, which also make it possible to find patterns that would be challenging to find by hand [15]. The next section discusses how AI and ML have become effective techniques for tackling transport route optimization problems. Large datasets may now be analyzed because of these technologies, which also make it possible to find patterns that would be challenging to find by hand.

- **Real-Time and Data-Driven Routing:** AI continuously analyzes data from GPS, traffic systems, and weather forecasts to dynamically adjust delivery routes. This ensures timely deliveries, avoids congestion, and enhances overall route efficiency.
- **Advanced Algorithmic Planning:** Using ML, DL, and reinforcement learning, AI identifies optimal paths and improves decision-making over time. These intelligent algorithms adapt to new data and refine routing strategies automatically.
- **Cost Reduction and Fleet Efficiency:** Optimized routing reduces fuel consumption, idle time, and delivery delays. At the same time, AI improves fleet utilization by assigning vehicles more effectively, maximizing load capacity and reducing operational waste.
- **Predictive Maintenance and Competitive Advantage:** AI monitors vehicle health through sensors, enabling proactive maintenance before failures occur. Combined with automated logistics decisions, this ensures smoother operations and gives companies a competitive edge in a fast-paced market.

B. AI in Transportation

The transportation sector has been steadily evolving over the years. The first mechanically powered marine vehicle was launched in 1787, when the wheel was invented in 3500 BC, allowing for the creation of the vehicles. Since then, the industry has advanced significantly with the development of cars, trains, and aircraft. The next phase of its development is represented by AI in the transportation sector. Transportation has now become intelligent.

C. Early Applications of AI in Transportation

Transportation has been using AI algorithms for many years. Because the earliest smart systems were tested and improved in labs and academic circles, the technology was quietly changing the industry without the general public noticing. Here are some of the earliest applications.

- Self-driving cars. The development of autonomous vehicles has been a problem for the AI community since the 1960s. The first prototypes were developed in the 2000s, but they couldn't examine a lot of things that happen on the road, such as traffic and pedestrian behavior. The 2004 developments in sensing and machine learning technologies sped up the creation of AI software for self-driving automobiles [16].
- Route Planning and Optimization. Route optimization solutions started gaining traction with the rise of computerized systems. One early example is UPS's ORION system, which was developed using AI principles and started in the late 2000s. Route planning systems back then employed artificial intelligence (AI) to determine the quickest routes while accounting for traffic, road closures, and distance.
- Traffic management. The earliest traffic optimization systems, such as the Sydney Coordinated Adaptive Traffic System (SCATS), were created in the 1970s and started to be implemented in many nations throughout the world in the early 1980s. However, artificial intelligence just recently entered the fray to automate a few simple manual tasks.

D. Current Applications of AI in Transportation

AI is essential to the transformation of Intelligent Transportation Systems (ITS) because it makes data-driven decisions, real-time monitoring, and predictive capabilities possible. Through sophisticated computer vision, DL, and ML approaches, AI improves a number of transportation components, resulting in systems that are safer, more effective, more responsive.

AI in Automated Driving Systems

AI technologies are integral to the development of autonomous vehicles (AVs) and advanced driver assistance systems (ADAS). These systems use AI, real-time object recognition, and decision-making under dynamic conditions. AI-driven Automated Driving Systems (ADS) perform complex driving tasks by processing sensor data from LiDAR, cameras, radar, and GPS. These developments are meant to lessen traffic jams and increase road safety, enhance fuel efficiency, and alleviate parking challenges by enabling vehicles to operate independently and cooperatively in smart environments.

AI in Transportation System Management and Operations:

AI supports intelligent traffic management by analyzing vast datasets from traffic sensors, cameras, GPS, and historical records. Predictive models enable accurate forecasting of traffic conditions, accident likelihood, and congestion hotspots. AI algorithms are used for dynamic traffic signal control, route optimization, and demand-responsive transit scheduling. Deep learning techniques can predict short-term vehicle trajectories, which is especially useful in data-scarce environments. Furthermore, AI enhances multimodal transport coordination, ensuring optimal utilization of infrastructure and improved reliability, safety, and operational efficiency across transportation networks.

Road Condition Monitoring

While local councils and National Highways keep an eye on major roads and the Strategic Road Networks, monitoring of smaller, less-travelled roads and residential areas typically relies on public reports of poor conditions. In transportation artificial intelligence systems, computer vision and machine learning algorithms can now automatically detect problems on surrounding structures and road surfaces, doing away with the need for on-site inspections. It uses images captured by drones or stationary cameras to detect potholes and assess the volume of road damage. With AI solutions, authorities can speed up road repair all around the city, not just major traffic-dense roads, and, what's more important, increase safety.

Smart Parking Management

Navigating through traffic and dodging speeding tickets are challenging enough, but finding a parking spot in a packed lot or busy city center can be equally daunting. Thankfully, artificial intelligence in transportation offers a helping hand, making this daunting task a bit easier. By integrating computer vision, parking lots equipped with sensors can monitor available spaces, while cameras and automatic number-plate recognition identify parked vehicles and track their parking duration.

AI in Logistics and Supply Chain Management

Transportation logistics firms and retailers try to maintain seamless supply chains, and with AI in logistics and transportation, that's not only achievable but also effective [17][18]. Delivery route optimization, reduced fuel consumption, sequencing of deliveries is just some of the aspects that can be improved with artificial intelligence. AI also makes it possible to predict product demands, stock needs, and customer requirements with better precision. So, it's not surprising that Gartner predicts that by 2024, half of supply chain businesses will spend money on AI-powered apps with sophisticated analytics features.

V. CHALLENGES AND OPPORTUNITIES IN INTELLIGENT TRANSPORTATION SYSTEMS

The integration of advanced technology into ITS raises several concerns regarding public safety and the security of personal data [19]. Based on the analysis efforts to address some challenges:

- **Further involvement of IoV (Internet of Vehicles):** The centralized control algorithm serves as the foundation for most of the existing traffic operating tactics. When the situation gets more complicated, this requires a large amount of computer power. May use IoV technology to give each vehicle a piece of the decision-making responsibility. It is possible to provide a decentralized approach by enhancing the exchange of information amongst vehicles, which might guarantee system scalability and offer effective traffic operation services.
- **Utilization of multiple-source data in ITS:** Through multi-source data fusion, which may produce complementary data when contrasted to a single source, the uncertainty associated with the individual sources may be reduced, leading to a better understanding of the observed situation. Additionally, installing and maintaining a suite of sensors is significantly less expensive. The system performance marginally impacted and a malfunction affecting one or more sensors will only slightly lower the penetration rate. May utilize ITS to get real-time traffic data from several sources. This consequently enables us to better oversee the transportation system.
- **Automated driving:** As communication and sensor technologies advance, commercial autonomous driving soon be available, and associated technologies become a focus of study. It affects traffic operations as well. Scientists are investigating how autonomous car technology might reduce traffic and fuel consumption in addition to making automobiles safer.
- **Model Validation:** There is no appropriate method to verify the accuracy of the many transport models that have been presented. On the one hand, because of the complexity of the transportation system, simulation cannot accurately forecast the real world. However, a large-scale confirmation of reality is not feasible may soon be because ITS has advanced, it is now possible should use more data in order to lessen the bias between simulation and the real world.
- **Security:** The security of technological devices is a continual worry. Security has always been a part of the protocols that have been created between vehicles and between vehicles and infrastructure, whereas personal computer and Internet communication security features were mostly incorporated as an afterthought. More broadly, computer hackers may target ITS, resulting in traffic jams and crashes or collect personal data.

VI. LITERATURE REVIEW

This section reviews AI-based route optimization techniques in Swarm intelligence, reinforcement learning for dynamic routing, and machine learning for traffic prediction are some of the methods that Intelligent Transportation Systems (ITS) emphasize. These approaches aim to improve travel efficiency, reduce congestion, and support real-time decision-making.

Song and Fan (2025) the simulation results, implemented using NS3 for real-world traffic scenarios, show improvements in route selection accuracy, collision avoidance, and energy efficiency compared to traditional routing methods. Specifically, the proposed system achieved a route selection accuracy of 95%, a collision avoidance rate of 95%, and reduced the communication latency to 105 ms, outperforming the other two methods. Furthermore, energy consumption was minimized and reduced to 85 J per route. These results highlight the potential of BDI-based routing with generative AI to improve ITS performance, particularly in real-time traffic management [20].

Wu et al. (2025) firstly, for the optimization of phase shift, transmission power and beamforming caused by the introduction of star-RIS, the block coordinate descent method and Lagrange dual algorithm are used to simplify the solution. Secondly, for system delay and global model training, federated learning (FL) algorithm based on double deep Q-network (DDQN) is utilized. This approach leverages policy optimization and data privacy protection to provide an intelligent resource optimization scheme for ITS. In addition, Numerical analysis and comprehensive simulations are

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used to confirm that the suggested algorithm works. The results show that the algorithm enhances the adaptability and service quality of the system significantly [21].

Qiao et al. (2024) suggested using a lengthy short-term memory network in conjunction with advantage actor-critic reinforcement learning to improve security. By extending the use of security improvement techniques to intelligent traffic systems, work ensures the physical safety and dependable functioning of ICPS by detecting and eliminating assaults in real time. The analysis and testing findings demonstrate method's efficacy and processing time efficiency [22].

Ding et al. (2024) showed that the error rate of traffic flow prediction during peak hours is as low as 0.81%, and signal control optimization reduces the average traffic delay by 15%. By implementing improved traffic management measures, the average annual accident rate has decreased by over 40%, and user satisfaction has increased by 30%. It can be found that the 6G-based intelligent traffic flow control system can effectively enhance the accuracy and response speed of traffic prediction, optimize signal control, remarkably reduce the accident rate, and improve the overall satisfaction of users [23].

Du (2023) Experimental findings show that the suggested method may produce excellent results and is a useful strategy for dealing with these kinds of problems. The model constructed is suitable for scenarios involving multiple centers, multiple demand points, and an open system, showing both reasonability and effectiveness. In comparison to soft and hard time window configurations, the use of fuzzy time windows is both reasonable and effective, concurrently illustrating the impact of fuzzy time window settings on customer satisfaction and model solutions [24].

Wang et al. (2023) The purpose of Transportation 5.0 is to progress and revolutionise use of innovative and cutting-edge technology, especially artificial intelligence, in the transportation industry. Primary research and conclusions over the past ten years are succinctly outlined in this document. Research and development for the future generation of intelligent transportation systems is concentrated in three key areas Transportation operating systems, transportation scenarios engineering, and transportation foundation models [25].

Wang and Wang (2022) The case study and simulation results demonstrate the accuracy and superiority of the use of predictive control models to dynamic route optimization in real time. The most crucial aspect of the model technique is the use of the static driving route and the anticipated driving time as control targets. By figuring out the worldwide dynamic best solution for the quickest route and the required travel time, it may adapt to a driver's needs. The suggested model algorithm is innovative and has real-world uses [26].

Table I presents a summary of the literature review, highlighting each study's focus, strategy, important discoveries, difficulties, and suggested future paths

Table 1: A summary of AI-based route optimization techniques in Intelligent Transportation Systems (ITS)

Reference	Study On	Approach	Key Findings	Challenges	Future Direction
Song and Fan (2025)	BDI-based routing in ITS	Generative AI with Belief-Desire-Intention (BDI) model	Achieved 95% accuracy in route selection and collision avoidance; reduced latency to 105 ms and energy consumption to 85 J	Integration with real-time, large-scale data	Expanding BDI-GAI models for broader ITS applications
Wu et al. (2025)	Resource optimization in ITS	FL with DDQN and block coordinate descent	Improved system adaptability and QoS using federated learning; supports privacy	High system complexity; convergence issues	Optimizing FL models for latency-sensitive ITS scenarios
Qiao et al. (2024)	ITS security enhancement	Advantage Actor-Critic + LSTM	Ensures physical safety and attack mitigation in real-time; efficient	Real-time detection accuracy under variable threats	Extending to broader ICPS/ITS

			processing		threats and adaptive defense
Ding et al. (2024)	Traffic flow prediction and control	6G-based intelligent control system	Reduced error rate to 0.81%; 15% drop in delay; 40% fewer accidents	Implementation cost, infrastructure requirements	Full-scale deployment of 6G ITS systems
Du (2023)	Routing with time constraints	Fuzzy Time Window Model	Improved customer satisfaction and flexible routing in open systems	Complexity of fuzzy logic in real-time applications	Enhanced decision-support systems for multi-center logistics
Wang et al. (2023)	Vision for next-gen ITS	Transportation 5.0 with AI foundations	Introduced Transportation Foundation Models and OS for ITS	High abstraction; practical implementation lacking	Development of standardized ITS operating systems
Wang and Wang (2022)	Route optimization in real time	Predictive control with static + dynamic inputs	Achieved global dynamic shortest path and satisfied user-defined timing	Scalability in high-density environments	Integration into navigation systems for personal vehicles

VII. CONCLUSION AND FUTURE WORK

In order to real-time communication technologies, the IoT, and ITS are being combined with AI to improve traffic control, safety, and operational efficiency. In countries like India, where road networks are vast and accident rates are high, AI-driven route optimization using models such as reinforcement learning and LSTM enables data-driven decision-making, predictive analytics, and dynamic traffic adjustments. These innovations help reduce congestion, travel time, fuel consumption, and accident risks. Additionally, technologies like V2X, DSRC, and C-V2X support seamless vehicle and infrastructure communication. Despite these advancements, challenges remain in areas such as cybersecurity, communication reliability, and data privacy, highlighting the need for more robust and secure systems.

Future research will focus on integrating 6G and edge computing to enhance real-time processing, applying federated learning for privacy-preserving AI models, and developing sustainable routing systems to minimize environmental impact. Additionally, greater emphasis will be placed on securing ITS infrastructure against cyber threats and designing unified platforms for intelligent, adaptive, and inclusive transportation management.

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