

INTELLIGENT TRANSPORTATION SYSTEMS IN SMART CITIES

Filip Popovski

Faculty of Technical Sciences, UKLO

filip.popovski@uklo.edu.mk, <https://orcid.org/0000-0001-8382-730X>

Hristina Dimova Popovska

Faculty of Information and Communication Technologies, UKLO

hristina.dimova@uklo.edu.mk, <https://orcid.org/0009-0003-3295-4538>

Gorica Popovska Nalevska

Department of Psychology Gavriilo Romanovic Derzavin Bitola

popovska.g@gmail.com, <https://orcid.org/0000-0002-2271-1618>

Abstract

A key element in the functioning of modern environments is traffic. Increasing the number of vehicles in urban areas creates serious traffic congestion and environmental pollution. Such problems are especially pronounced in cities that are tourist hubs and this further hampers the ongoing traffic system. In this direction, intelligent transportation systems are setting the stage in smart cities and offering a modern approach to traffic management. Transportation systems that are based on integrating advanced technologies such as the Internet of Things, artificial intelligence, sensing networks, and real-time data analytics are already becoming part of intelligent smart cities. Technologies that allow traffic monitoring, traffic detection, and decision-making are giving the city an improvement in its transportation system. This study proposes a conceptual architecture of an intelligent transport system that will include multiple layers such as a sensor layer, a communication layer, a data processing layer, and an application layer. This architecture provides for the integration of smart components such as traffic lights, a parking management system, and traffic monitoring mechanisms. The proposed model becomes the basis for future development and implementation in intelligent transportation solutions to reduce congestion, improve safety and maintain safety.

Keywords: *intelligent transportation systems, smart cities, Internet of Things, artificial intelligence, transportation.*

1. INTRODUCTION

The rapid development of urbanization and the increase in the number of vehicles in modern cities pose a serious problem associated with traffic congestion, environmental pollution, and a decrease in the efficiency of transportation systems. Such problems show that there is a need to introduce an intelligent solution that will enable better traffic management. The concept of smart cities, in its part, intelligent transport systems are one of the most important components to enable safe urban mobility [2]. The integration of information communication technologies, the Internet of Things, sensor networks, and artificial intelligence into intelligent transportation systems aims to monitor, analyze, and

optimize traffic in real time [2]. By using these technologies, adaptive traffic management and reduction of emissions of harmful gases in the same environment are possible [3]. Recent years have been significant because we have seen a huge increase in research in the field of intelligent transport systems as well as their role in smart cities. New research shows that the integration of artificial intelligence, the Internet of Things allows for the development of adaptive systems to be able to manage traffic, smart traffic lights, and parking systems [4]. Modern solutions also enable traffic data analysis and support decision-making to optimize transportation in real time [5]. The concept of smart city and tourism also demonstrates the need to integrate intelligent transport solutions as part of modern infrastructure [6].

The aim of this paper is to propose the architecture of an intelligent transport system as part of a smart city. The architecture is based on a multi-layer approach that includes sensor devices, a data processing system, communication infrastructure, and an application layer to manage traffic. The paper aims to demonstrate how the integration of modern technologies can bring improved urban mobility and create a basis for the further development of intelligent transport solutions.

2. RELEVANT RESEARCH

The last few years have been significant for intelligent transportation systems as the most significant area in the development of a smart city. The growth in the number of vehicles and the need for mobility have created the need for a modern traffic management solution [13]. Smart cities use IoT-based intelligent systems, cloud infrastructure, and real-time analytics to improve security [13].

Research shows that the introduction of intelligent transport systems provides an opportunity to reduce traffic congestion and improve mobility through adaptive traffic management systems [3]. According to Elassy, modern information systems integrate technologies such as Vehicular Ad-Hoc Networks, intelligent traffic lights, and real-time communication [10]. These technologies make it possible to automatically adjust traffic depending on density and road conditions. The application of artificial intelligence in transportation systems enables data analysis and congestion prediction [7]. Modern models for vehicle recognition, traffic tracking, and transportation management use machine vision and deep learning algorithms [12]. Such solutions reduce wait times, improve vehicle flow, and increase safety.

Research focusing on parking systems and smart mobility shows an increase in parking spaces. According to Wang and collaborators, IoT-based systems for smart practice allow for the optimization of parking spaces and the reduction of movement to search for a free parking space [11]. Also, modern smart mobility systems use mobile applications and platforms to provide real-time traffic information [6].

The concept of smart tourism also further demonstrates the need for intelligent transport systems in tourist cities [4]. In tourist environments where there is seasonal variation and an increase in the number of tourists, pressure is placed on the transport system and the integration of intelligent transport solutions is required [4].

It can also be said that modern research is gearing towards the integration of various technologies into intelligent transport systems. According to Zhang and collaborators, communication between vehicles and infrastructure is a significant segment in the development of urban mobility. Therefore, such systems allow for real-time data exchange [14].

Research related to Big Data and Cloud computing shows the processing of large amounts of traffic data and thus shows that better analysis of transport processes is allowed [15]. According to Kumar et al., intelligent traffic management systems enable adaptive traffic light regulation and optimization of traffic flows [9], and Ahmed et al. show in their research increased communication with IoT devices resulting in the need for data protection mechanisms [1].

Modern smart parking systems are an important segment within intelligent transportation solutions, which is why Lin et al. apply IoT sensors to optimize parking space and reduce unnecessary vehicle movement in urban environments [10]. Research related to intelligent traffic lights shows that adaptive regulation of traffic signals allows for better vehicle flow [8].

In addition to numerous research in the field, there is still a need for the development of an integrated architecture that will enable coordinated communication with the components within the framework of smart cities. Therefore, this paper proposes a conceptual architecture of an intelligent transportation system based on the Internet of Things and artificial intelligence to improve urban mobility.

3. RESEARCH METHODOLOGY

The research is based on the Design Science Research (DSR) methodological approach used for the design and development of innovative information solutions. Such an approach makes it possible to identify existing problems, analyze modern technologies and create a model that aims to improve traffic management within a smart city.

Within the framework of this research, an analysis of the current literature related to intelligent transportation systems, smart cities, the Internet of Things, and artificial intelligence is done. Existing architecture and models as well as smart parking systems are analyzed. Concepts of smart tourism and integration of intelligent transport systems in those cities are also analyzed.

The methodological approach consists of several stages. The first stage is to identify challenges in urban traffic such as congestion, reduced mobility and inefficient use of transport. The second stage is the analysis of modern intelligent transport technologies and their application. Based on the results obtained, a conceptual architecture of an intelligent transport system is designed. The architecture is based on a multi-layer system that has a sensor layer, a communication infrastructure, a data processing layer, and an application layer. The architecture envisages the integration of IoT devices, traffic monitoring systems, intelligent traffic lights, and smart parking systems to enable adaptive and coordinated management of traffic processes.

4. INTELLIGENT TRANSPORTATION SYSTEM ARCHITECTURE

The proposed architecture of the intelligent transport system is based on a multi-layered model that has the ability to collect, transmit, process and apply traffic data in the smart city sector. The primary goal of the architecture is to provide coordinated and adaptive traffic management through the integration of IoT devices, communication infrastructure, data processing modules, and application services. The architecture is composed of four layers: the sensor layer, the communication layer, the data processing layer, and the application layer.

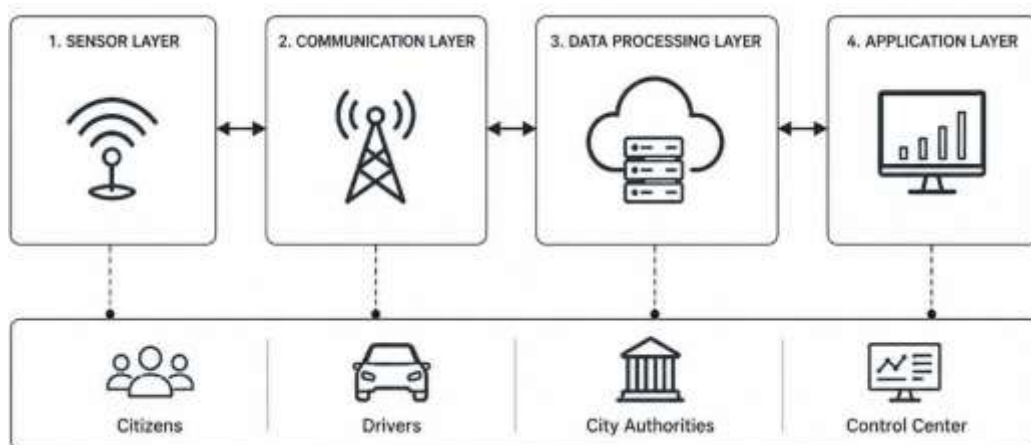


Figure 1. Conceptual Architecture of an Intelligent Transportation System in a Smart City

- **Sensor layer**

This layer is a fundamental part of the architecture of an intelligent transport system and its task is to provide real-time data collection of urban transport infrastructure. This layer provides continuous monitoring of traffic status through the integration of various IoT devices, sensors, and monitoring systems.

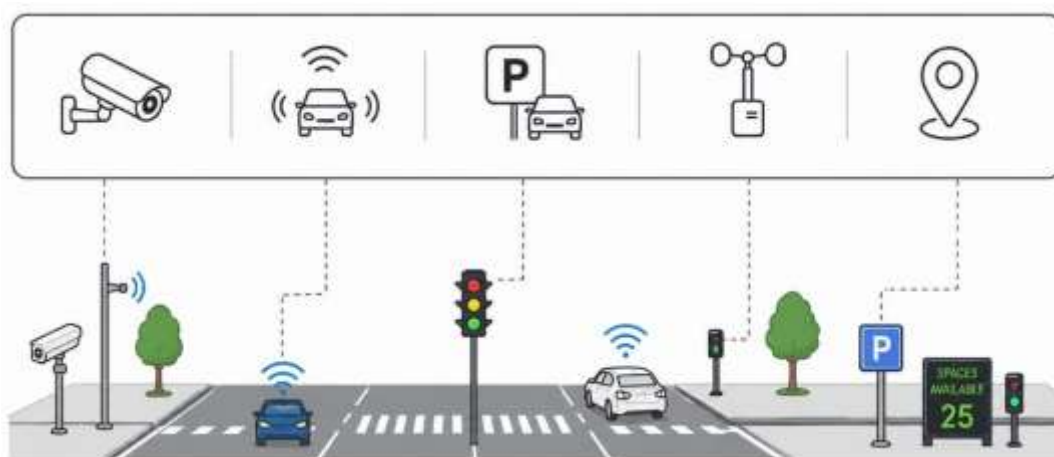


Figure 2. Sensor Layer in the Conceptual Architecture of an Intelligent Transport System

Part of the sensor layer are cameras used for video surveillance and vehicle detection, in addition to sensors that measure the density and speed of traffic, GPS systems that track the location of vehicles, and sensors for smart parking. The system can also integrate weather and environmental sensors and this will contribute to a better analysis of traffic factors.

The collected sensor data is transmitted to the communication layer where it is further used for processing and analysis. The advantage is that continuous information collection is ensured, and thus the system allows for traffic flows, pedestrian identification and support for adaptive traffic management. The sensor layer is one of the important components in intelligent transport systems because it provides accurate information about the functioning of the other layers in the architecture.

- **Communication layer**

This layer is an intermediary component between the sensor layer and the data processing layer. Its task is to ensure reliable and uninterrupted transmission of data from components in an intelligent transport system. Various communication technologies such as 5G networking, Wi-Fi communication, IoT Gateway devices, and cloud infrastructure are used in this layer. These technologies allow data from sensors and other IoT devices to be transferred to a central processing and analysis system.

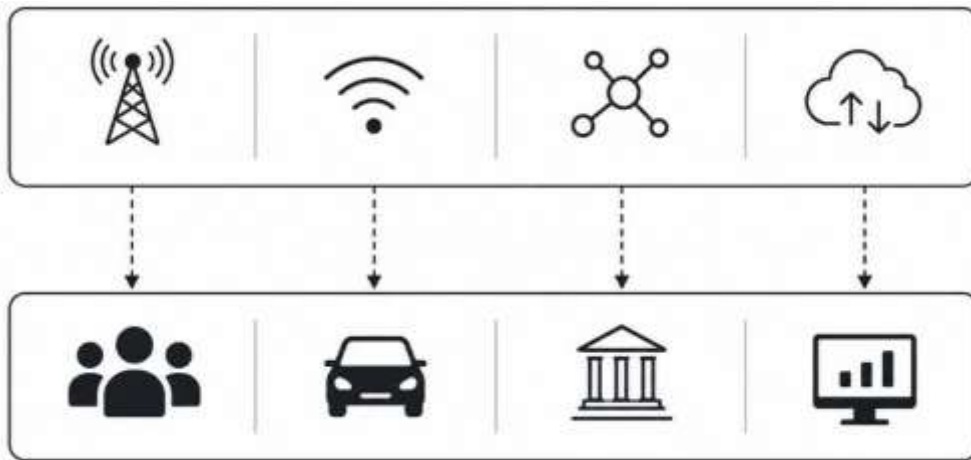


Figure 3. Communication Layer in the Conceptual Architecture of an Intelligent Transport System

The communication layer plays a significant role in providing real-time communication between transport infrastructure, vehicles, and traffic management systems. As part of such communication, the system reacts in a timely manner to changes in traffic conditions, the occurrence of traffic congestion and situations affecting urban mobility. Cloud infrastructure also provides centralized storage and exchange of data between various components and users in the system. IoT Gateway enables integration and communication between sensor types and communication protocols, which contributes to better interoperability and functionality of the system.

This layer is an important part of the proposed architecture because it provides stability and connectivity as well as efficiency in data exchange between layers of an intelligent transport system.

- **Data Processing Layer**

A central component in the conceptual architecture of an intelligent transport system is the data processing layer. Its primary task is to process, analyze and interpret the data it receives from the sensor layer and the communication layer in order to make intelligent decisions related to traffic management.

In this layer, data storage is done through the cloud and data storage infrastructure, as well as the integration of data from various sources. The collected information is then processed using algorithms for data analysis, machine learning, and artificial intelligence. This approach allows for traffic pattern recognition, traffic density analysis, and traffic forecasting. The data processing layer also enables the generation of recommendations and automated decision-making to optimize traffic processes. Through real-time data analysis, the system can adaptively manage traffic signals, send notifications, and support the use of transportation infrastructure.

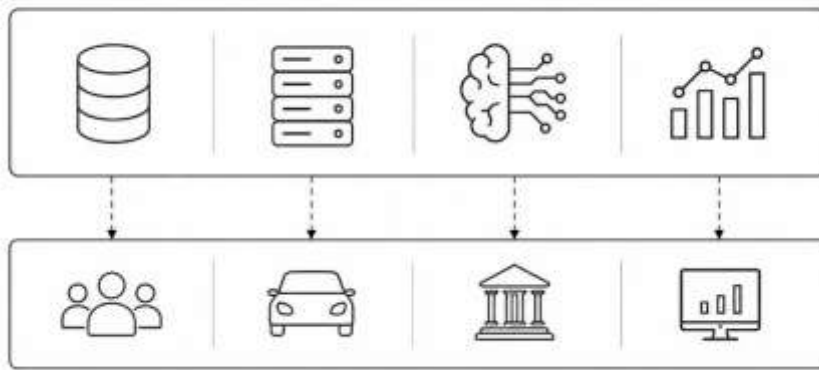


Figure 4. Data layer in the conceptual architecture of an intelligent transport system

Additionally, it can be concluded that it plays a significant role in intelligent transport systems as it provides the ability to transform large amounts of data into useful information that has contributed to urban mobility and supported intelligent traffic management.

- **Application layer**

The final layer in the conceptual architecture of an intelligent transport system is the application layer. Its role is to present the processed data in forms that are useful and functional for various users of the system such as citizens, drivers, municipal authorities and traffic management centers.

Part of this layer are smart traffic lights, parking management systems, monitoring panels, mobile apps, navigation apps, and notification systems. With these components, users receive real-time information about traffic conditions, available parking spaces, congestion, alternative routes and

warnings about various situations. In this part of the system, practical application of the results obtained from the data processing layer is provided. For example, if the system detects high traffic density, the application layer may support adaptive traffic light regulation, send a notification to drivers, or display information on the dashboard.

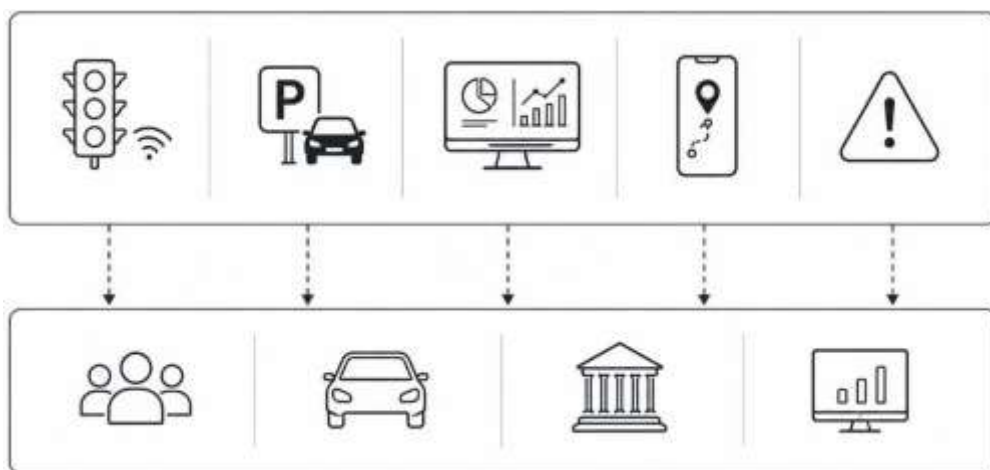


Figure 5. Application Layer in the Conceptual Architecture of an Intelligent Transport System

The application layer plays a significant role because it connects intelligent analysis with real-world applications in urban environments, enabling better traffic management, greater security, better user awareness and more efficient operation of the smart city.

5. DISCUSSION

The conceptual architecture of an intelligent transport system is a conceptual model based on the integration of modern information and communication technologies within smart cities. The architecture is designed according to the Design Science Research (DSR) methodological approach, which, through the analysis of existing research and technologies, defines a model for urban traffic management.

With the application of sensor devices, IoT technologies, and the communication layer, modern data acquisition and exchange are obtained. This approach allows for traffic flow monitoring, identification of critical points, and support for intelligent management. Also, the integration of cloud technologies and IoT Gateway devices allows for centralized management and communication of various components of the system.

The data layer plays a significant role in the proposed architecture because it allows the analysis and interpretation of large amounts of data and, using artificial intelligence and machine learning algorithms, can recognize various traffic patterns, analyze traffic density, and predict congestion. This section provides the basis for adaptive traffic management.

The adaptive layer aims to leverage the results obtained through smart traffic lights, parking management systems, monitoring, and mobile apps. With the help of these components, users receive real-time information about the state of traffic. The system also provides support to municipal authorities and staff management centres by monitoring and analyzing transport processes.

The main advantage of the proposed model is the integration of different technologies and systems into a single system. Additionally, the architecture can be adapted to different urban environments, including tourist cities.

Like every model, this model has its own model has not been implemented and tested in a real-time environment. Also, the success of such systems depends on the availability of an adequate communications infrastructure and the need to anticipate aspects related to security, privacy, and data protection.

6. CONCLUSION

The paper proposes a conceptual architecture of an intelligent transport system based on the integration of IoT technologies, communication infrastructure, data analytics and artificial intelligence within a smart city. The proposed model is designed to improve urban traffic management, optimize transport infrastructure and urban mobility.

The organization of this architecture is divided into several layers: the sensor layer, the communication layer, the data processing layer, and the application layer. Such an organization allows for data collection and processing, as well as the application of intelligent functionalities to manage traffic. Additional functionality includes the integration of artificial intelligence and traffic situation prediction.

As part of this research, an analysis of relevant research and technologies related to intelligent transport systems was performed. Based on the analysis, an architecture has been defined that allows the integration of various components and technologies into a single intelligent traffic management system.

The proposed model provides a conceptual basis for the further development and implementation of intelligent transport solutions in modern urban environments. Although no practical application has been made within this paper, the architecture is an opportunity for further research related to testing, evaluation, and integration of complementary technologies. The implementation of such intelligent transportation systems can contribute to reducing traffic congestion, improving safety, and making smart cities function more efficiently.

References

- [1] Ahmed, S., Rahman, M., & Hasan, T. (2025). *Security and privacy challenges in IoT-based smart transportation systems*. *Sensors*, 25(3).
- [2] Algherbal, E. A., & Ratrout, N. T. (2025). *Smart cities and intelligent transportation systems: Integration of autonomous vehicles and their impact on congestion and safety*. *Transportation Research Procedia*, 84, 504–511.
- [3] C.INEA. (2025). *Intelligent transport systems in the EU*. European Climate, Infrastructure and Environment Executive Agency, European Union.
- [4] Dimova Popovska, H., & Popovski, F. (2023). *Conceptual and integrated smart tourism model*. In *Proceedings of the 20th International Conference on Informatics and Information Technologies (CIIT 2023)* (pp. 25–28).
- [5] DolatAbadi, S. H. H., Hashemi, S. M. H., Hosseini, M., & AliHosseini, M. A. (2025). *Revolutionizing traffic management with AI-powered machine vision: A step toward smart cities*.
- [6] Elassy, M. (2024). *Intelligent transportation systems for sustainable smart cities*. *Transportation Engineering*, 16, 100252.
- [7] Elbasha, A. M., & Abdellatif, M. M. (2025). *AIoT-based smart traffic management system*.
- [8] Islam, M. R., & Khan, F. (2025). *AI-based intelligent traffic light management system*. *Transportation Engineering*, 18.
- [9] Kumar, P., Singh, A., & Patel, R. (2025). *Adaptive traffic signal control using artificial intelligence*. *Smart Cities*, 8(1), 77–95.
- [10] Lin, C., Chen, Y., & Zhao, H. (2025). *IoT-based smart parking systems for urban mobility*. *IEEE Internet of Things Journal*, 12(1), 224–238.
- [11] Ma, X., & Xue, H. (2020). *Intelligent smart city parking facility layout optimization based on intelligent IoT analysis*. *Computer Communications*, 172, 10–18.
- [12] Pajkovski, D., Apostoloska Kondoska, M., & Dimova Popovska, H. (2025). *A smart city model for an intelligent traffic light decision system*.
- [13] Puzio, E. (2025). *The role of intelligent transport systems and smart technologies in smart cities*. *Energies*, 18(10).
- [14] Sharma, S., & Gupta, R. (2025). *Big data analytics and cloud computing in intelligent transportation systems*. *Future Internet*, 17(2).
- [15] Zhang, Y., Liu, H., & Wang, X. (2025). *Vehicle-to-infrastructure communication in smart cities*. *IEEE Access*, 13, 11452–11468.