SMART CITY CONSTRUCTION AT ITS BEST: THE URBAN CASE STUDY OF SMART TUNNEL LIVELIHOOD SYSTEM

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ABSTRACT

This paper explores the development of Smart City Construction that prioritizes the needs of citizens. We highlight the Smart Tunnel Livelihood System as a case study, which provides an innovative and practical solution to improve safety, traffic efficiency, and emergency response in urban tunnels. In today's cities, smart tunnels should offer a revolutionary way to manage emergency vehicle traffic. Our system consists of three crucial components: traffic flow monitoring, closed-loop data sharing applications, and real-time traffic monitoring and guidance. By integrating these three components, we can address the challenges faced by smart tunnels, enhance their safety, and improve traffic efficiency in urban areas. Through our multi-layered approach to data management and real-time traffic monitoring, we demonstrate how to design a solution that meets the demands of citizens in the modern Smart City Construction.

KEYWORDS

Smart Tunnel, IoT system, Smart City, Real-Time Control, Tunnel Livelihood System

1. INTRODUCTION

The rise of smart cities has been driven by technological advancements and the urgent need to address environmental and urbanization issues. Many cities worldwide are adopting smart city technologies to improve the quality of life for citizens, enhance urban infrastructure, and promote sustainable development, such as IoT technology is used for supply chain management (Nagarajan et al., 2022), and blockchain technology is used in intelligent transportation system (Ullah et al., 2023). Moreover, smart city design involves much more than the merely physical structures but includes the entire framework as well.

Yet, the rapid development of smart cities has brought to light concerns about the potential negative impact on vulnerable groups. Therefore, it is essential to ensure that smart city technologies cater to the needs of all citizens, including those with urgent medical requirements (Kamtam et al., 2022). Issues concerning emergency medical services' efficiency and quality have become increasingly pressing, given the life-threatening consequences of delayed response times. An efficient system for the implementation of smart city technologies is vital to achieving the desired results in the "last-mile" delivery of services.

In this paper, we contend that smart tunnel systems have immense potential in mitigating the urgent challenge of emergency medical transportation in developing smart cities. To begin, we introduce the fundamental components of smart tunnel systems, as well as the challenges posed by emergency medical transportation to the transportation system. Subsequently, we present an assessment of the hurdles associated with implementing smart tunnel systems in urban areas that are primed for smart city infrastructure. Then, we propose solutions for the control and integration of data systems in smart tunnels. Lastly, we highlight the implications and significance of this experimental approach. Overall, this paper showcases that intelligent tunnel systems possess the capability to address the exigencies of emergency medical transportation and represents a crucial step towards smart city development.

1.1 Development of Smart Cities

Smart cities are a cutting-edge urban development paradigm, driven by the urgent need to overcome diverse challenges stemming from the rapid pace of urbanization (Mohanty and Kumar, 2021). They involve the integration of various urban systems, such as energy, transportation, and government services, as well as the implementation of innovative technological solutions that enable comprehensive and effective planning, management, and service delivery. Smart city concepts are founded on more sustainable, inclusive, and resilient approaches to urban living, nurturing a symbiotic relationship between the physical and digital environments. The ultimate goal of smart cities is to enhance people's quality of life by enhancing their living conditions in both physical and digital spaces. By forging a closer connection between these two dimensions, smart cities strive to deliver a more comfortable, convenient, and sustainable living environment that fulfills the needs and expectations of present-day urban communities.

A multitude of smart cities have already appeared around the world, including Singapore, Barcelona, and London, among others (Joss et al., 2019). The development of smart cities is a continually evolving process. Academics have discussed extensively the possible benefits and challenges related to smart city technology. Some scholars assert that the use of smart city technology can improve urban living standards through effective and thorough planning and management. For example, Deakin and Al Waer (2011) affirm that smart cities can promote social and economic development through the application of ICT solutions. On the other hand, other researchers have highlighted potential issues related to smart city technology, such as data privacy, security, and accessibility. Zanella et al. (2014) warn about the requirement for ethical policies and regulations to prevent data breaches and cyberattacks in the development of smart cities. Furthermore, scholars have emphasized the importance of engaging stakeholders and fostering public-private partnerships to guarantee equitable distribution and participation in the development of smart cities (Nam and Pardo, 2011).

However, the fast-paced development of smart cities has also raised concerns about potential negatives impacts on vulnerable groups, particularly those in urgent need of medical attention. While smart city technologies can enhance the efficiency and quality of emergency medical services, it is crucial to ensure that they cater to the needs of all citizens, including those who may not have access to the latest technologies or who may face other healthcare-access barriers.

1.2 Focus on Urgent Needs

In order to ensure the safety and well-being of vulnerable groups, such as those in need of emergency medical attention, prioritizing their needs should be a vital consideration for smart city technologies. For instance, it is essential to ensure that emergency medical services are accessible to all citizens, irrespective of their socioeconomic status or location. The fast and efficient transportation of patients to medical facilities is of utmost importance, especially in time-sensitive cases, such as heart attacks, strokes, and trauma injuries. Therefore, smart tunnels play a crucial role in addressing emergency medical traffic challenges in urban traffic systems, which often face heavy traffic loads, frequent accidents, and extensive operational and maintenance restrictions. By linking various hospitals and emergency departments, smart tunnels offer a dedicated and streamlined transportation route for emergency medical services to reduce response time and ultimately improve patient outcomes.

1.3 IoT Technology

The Internet of Things (IoT) is an innovative technology that comprises of tangible devices connected to the internet via sensors and protocols. It allows for the exchange and communication of information among these connected devices. The IoT technology enables functions such as intelligent recognition, positioning, tracking, supervision, and control, making it a valuable asset for a variety of fields, including transportation, medical care, and energy management (Li et al., 2014) [9]. By utilizing IoT sensors, it is possible to obtain real-time monitoring of environmental parameters and facility status information, which can be processed, analyzed, and controlled to detect anomalies and enable the automatic activation of emergency procedures. The integration of IoT technology in transportation infrastructure marks a significant step towards smarter transportation systems, which can enhance urban mobility and improve the quality of life of city-dwellers.

Furthermore, by monitoring traffic patterns, reducing congestion, and minimizing energy consumption, IoT-powered smart tunnels could promote the creation of greener transportation networks, thereby improving environmental sustainability.

1.4 Smart Tunnel Systems

Smart tunnel infrastructure is a novel approach to managing tunnel operations and enhancing transportation efficiency. By leveraging advanced sensing and control technologies such as IoT, smart tunnels enable a wide range of applications such as tunnel accident detection systems (Kim et al., 2019), tunnel crack detection systems (Zhong et al., 2019), tunnel brightness detection systems (Li et al., 2019), as well as traffic monitoring, management, and ventilation control. Additionally, smart tunnels represent a groundbreaking solution to the challenge of emergency vehicle traffic in cities. With the aid of sophisticated sensors and control systems, smart tunnels can detect approaching emergency vehicles and adjust traffic flow automatically, allowing seamless passage without interruption. This approach can substantially diminish emergency response times and enhance patient medical outcomes. Smart tunnel systems offer a promising solution to the problems of emergency vehicle traffic in urban areas and provide an opportunity to optimize the efficiency of emergency medical services.

2. PROBLEMS AND CHALLENGES

This article aims to identify an appropriate case study for the deployment of a smart tunnel system, which meets certain criteria such as addressing specific societal needs, having adequate space for installation across two lanes, and having essential infrastructure and information technology to enable the creation of a complete IoT system. The integration of a smart tunnel system in a practical context will offer insight into the challenges and opportunities that accompany such infrastructural changes. The chosen case study must have urgent requirements for enhancing emergency response and traffic management, as well as fundamental infrastructure and information technology crucial for the implementation of essential IoT systems. One instance could be a bustling urban highway plagued by frequent traffic congestion and high reliance on emergency medical services. Nevertheless, executing this implementation process demands substantial investment in both financial and logistical resources.

2.1 Selected Case

The case study of Changsha City, China satisfies the three criteria mentioned in this article for implementing the smart tunnel system. Firstly, with a significant proportion of the population over the age of 65, accounting for over 15% of the permanent residents, Changsha City requires advanced healthcare infrastructure to address medical emergencies. The smart tunnel system can assist with this by improving traffic flow and enabling quicker emergency medical response times.

Secondly, Changsha City's location, with one river and two banks, provides ample space for the installation of the smart tunnel system. The Xiangya Road Cross River Tunnel, connecting multiple medical institutions, Xiangya Hospital and Third Xiangya Hospital, two Chinese famous top hospitals, is currently under construction, while nearby healthcare facilities like Hunan Maternal and Child Health Hospital and Hunan Cancer Hospital further emphasize the need for efficient emergency response. China Ambulatory Surgery Alliance announced that in 2021, with an annual total of over 3.473 million outpatient and emergency visits and 102,000 surgeries in Xiangya Hospital, respectively, Changsha City has a large number of patients requiring medical attention. Geographic map of Xiangya Road Cross River Tunnel as shown in Figure 1.

Lastly, the selected case study should have basic infrastructure and information technology in place, enabling the implementation of necessary IoT systems. The Xiangya Road Cross River Tunnel is planned to be the main road of the city, which is a two-way six-lane road. The length of the North line tunnel is 3320m, the length of the south line tunnel is 3648.24m, and the design speed is 50km/h for the main line tunnel and 35km/h for the on-ramp tunnel. The entrance and exit are equipped with video analysis cameras for vehicle detection. With such condition, IoT technology can create green channels for medical institutions to transport critically ill patients effectively, although ensuring safety, efficiency and normal operation under traffic loads, traffic accidents, and safety accidents is a major challenge.

Figure 1. Geographic map of Xiangya Road Cross River Tunnel

Thus, the case of Xiangya Road Cross River Tunnel provides a compelling example for implementing a smart tunnel system that can cater to specific societal needs. This innovative solution not only makes efficient use of available installation space but also enables the seamless transportation and treatment of a large number of patients in need of medical attention, as outlined in this article.

2.2 Challenges and Difficulties

There are several challenges that need to be overcome in order to implement the livelihood system into the smart tunnel. These include managing traffic in congested urban tunnels; integrating data and communication systems among hospitals, emergency departments and the tunnel management system; and ensuring ambulance priority management with the real-time emergency vehicle navigation.

First, managing traffic flow in urban tunnels requires innovative solutions that can seamlessly integrate with existing transportation systems while prioritizing emergency vehicle traffic. Urban tunnels are notoriously congested, so implementing comprehensive monitoring and control systems for smart tunnels is a complex task. The management and monitoring systems of a tunnel are typically part of different communication protocols and control systems, adding an extra layer of complexity. Therefore, designing a new smart tunnel system requires careful consideration to avoid disrupting the intricate network of existing systems and protocols, as even the slightest misstep could potentially disrupt an already complex system.

Integrating different data systems and platforms used by hospitals, emergency departments, and the tunnel management system presents another significant challenge. The healthcare industry has struggled with fragmented technology adoption due to the varying electronic health record (EHR) systems, communication protocols, and data formats used by different hospitals and emergency departments. Additionally, the data collection and analysis technologies and standards used by the tunnel management system may differ, adding another layer of complexity. Therefore, integrating different data sources while ensuring data integrity and security is crucial.

Lastly, real-time ambulance priority management presents a challenge. Traditional traffic control systems may not be adequate to ensure ambulances are given priority in congested tunnels. A smart city tunnel system must be equipped with real-time sensors and algorithms to detect ambulance presence and adjust traffic signals accordingly. Further, the system should provide real-time feedback to ambulance drivers about the estimated time of arrival to the destination hospital.

3. SOLUTION

To address the challenges facing smart tunnels in cities, enhance their safety, and improve traffic efficiency, this paper proposes a comprehensive set of solutions for a smart tunnel livelihood system.

The proposed program addresses the following three issues:

- Creating a complete smart tunnel livelihood system to monitor and control traffic flow;
- Opening the closed loop of multi-point data sharing and analysis applications;
- Enabling real-time traffic monitoring and guidance scenarios.

Intelligently managing and controlling urban tunnels presents significant challenges, particularly when it comes to achieving interoperability between multiple devices, sharing data, coordinating management, enabling collaboration, and facilitating rapid responses across different IoT platforms, public service entities (including medical institutions), and government control centers situated in multiple locations. To tackle these challenges, this top-level design approach employs three design dimensions: IoT cluster management, integrated data scheduling, and scenario-based command and dispatch systems.

The overall design aims to integrate new technologies with existing resources to enhance system efficiency. The system architecture, as illustrated in Figure 2, provides a comprehensive solution:

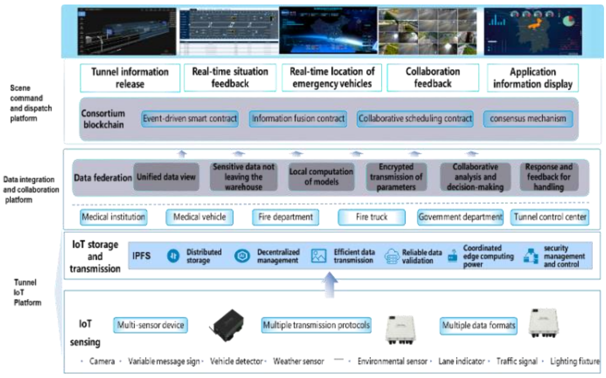
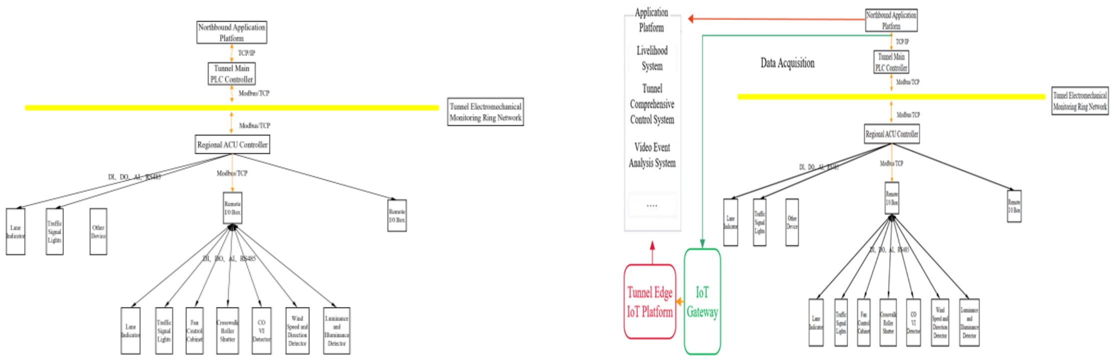


Figure 2. Overall Architecture of Smart Tunnel Livelihood System

3.1 Constructing a Tunnel Edge IoT Platform

Through analysis and evaluation, it is found that the current tunnel monitoring and communication systems consist of five systems, namely, the central computer system, fire alarm system (FAS), traffic monitoring system, environmental equipment monitoring system (BAS), and communication system, as well as CCTV and video detection systems. Each of the systems operates independently, and Programmable logic controller (PLC) is adopted as a mature communication solution. These five systems respectively meet the requirements for basic information collection and management in the tunnel, which constitute a classic scheme for tunnel monitoring and communication and ensure the completeness of electromechanical functions, reliability of technology, and safety of tunnel management, as shown in Figure 3(a).



(a) Current Tunnel Information and Control System (b) Tunnel Edge IoT Platform

Figure 3. IoT Technology Application in Tunnel Information and Control System

However, the entire system also faces several shortcomings: The traditional electromechanical system suffers from control separation and data isolation issues, with inadequate sharing and utilization of data and resources throughout the tunnel; the limited front-end sensing capabilities and absence of real-time sensing, automatic early warning, and rapid disposal are cause for concern; the PLC architecture's centralized control mode frequently experiences multiple faults and cannot provide equipment status point sensing, resulting in high troubleshooting costs; Finally, the overall architecture lacks the logic of intelligent IoT, necessitating the application of AI technology to attain visualized, measurable, controllable, and intelligent management.

To overcome these limitations, we propose establishing a tunnel edge IoT platform that facilitates integrated data collection, analysis, and sharing, sensor deployment for comprehensive event sensing, and AI-based smart management. Specifically, an IoT gateway will be installed on the main PLC controller in the tunnel, enabling data collection across different systems and devices. To unify device identifiers, a standardized tunnel state model will be established, addressing the problem of data and information isolation. The tunnel edge IoT platform will be built on the tunnel side, with application cases and models tailored to specific scenarios as depicted in Figure 3(b).

The proposed approach aims to enable a distributed control mode that enhances the integrated access and sharing of data resources, laying a conceptual foundation for advanced tunnel behaviours analysis and prediction. The solution will also deploy advanced sensors capable of comprehensive event sensing, facilitating automatic early warning and rapid disposal. The PLC architecture of the current system belong to a centralized control mode, which is prone to multiple faults and cannot realize point sensing of equipment status, resulting in high cost of troubleshooting; in contrast, this architecture allows for a more precise point sensing of equipment status, reducing the cost of troubleshooting.

By incorporating the logic of intelligent IoT, the tunnel edge IoT platform will utilize AI technology to enable visualized, measurable, controllable, and intelligent management, and will play a crucial role in supporting the development and implementation of tunnel intelligentization. The platform boasts compatibility with multiple communication protocols and data compression technologies to maximize data exchange efficiency, and thus reduce operational costs. With increasingly complex tunnel data and equipment, the platform's analytical capabilities will prove essential in identifying trends, anomalies, and potential hazards in tunnel operations.

Overall, the tunnel edge IoT platform represents a promising approach for addressing the shortcomings of the current tunnel monitoring and communication systems, allowing for enhanced and cost-effective tunnel management and maintenance. The platform's advanced sensing equipment, extensive data processing capabilities, and smart management logic will facilitate more proactive and data-driven decision-making and improve tunnel safety.

3.2 Data Integration Scheme Design

To enable efficient and reliable data sharing across multiple points, including healthcare institutions, government departments, tunnel control centers, and medical vehicles, a data integration platform based on data federation has been established. The platform facilitates data analysis, sharing, and application while ensuring that sensitive data remains local. A unified data view is provided for logical data integration to avoid security risks from data leaving the local environment. The integration platform also establishes different endpoint nodes for local computing, enabling local model training, deployment, computation, and secure transmission of encrypted parameters between different points.

Moreover, the integration platform provides coordinated control to implement related tasks in various scenarios, synchronous model computation, on-site response, and feedback coordination, all of which support the development of advanced applications. Serving as the core of the civil system's data operation, the data integration and collaboration platform is the foundation for secure and reliable data application among multiple endpoint nodes.

The above introduces the overall architecture and main functions of each part of the system. In this section, we mainly introduce how to break through the data loop of perception, decision-making, and control, and achieve efficient and reliable data sharing applications. The overall architecture of system data integration is shown in Figure 4. In the integration scheme illustrated in Figure 4, multiple endpoints are involved, including tunnel IoT devices, tunnel on-site management control centers, medical rescue institutions, and government management departments. Given the different data storage and processing capabilities among these endpoints, the heterogeneous and non-uniform data situation must be addressed in the system design, with a focus on resolving the storage, analysis, and transmission of massive IoT data. Furthermore, the security, timeliness, and reliability of data sharing among multiple endpoints must be ensured, along with the realization of a closed-loop business for data perception analysis, decision-making, and coordinated control among multiple endpoints.

In the case of this tunnel, the data required by the civil system comes from various data silos in the field of social governance. The internal data and system management of each party are complex, and significant variances exist in the types, attributes, and structures of the data. This makes data sharing and interaction nearly impossible in such a multi-party autonomous data environment. This article proposes a solution for data federation to facilitate data integration and cooperate learning. Various departments and institutions, as well as IoT devices, can use data federation to achieve layered integration, as shown in Figure 5. The data on the IoT side, the people's livelihood side, and the government side usually come from various departments and institutions and on-site sensing equipment. The internal data and system management of each party are more complicated, and the types, formats, and scales of data between each other are different. In order to solve problems such as difficult data sharing, high data privacy requirements, and slow response of data analysis applications, the data of various departments, institutions, and IoT devices can be layered and integrated in the form of data federation, as shown in Figure 5:

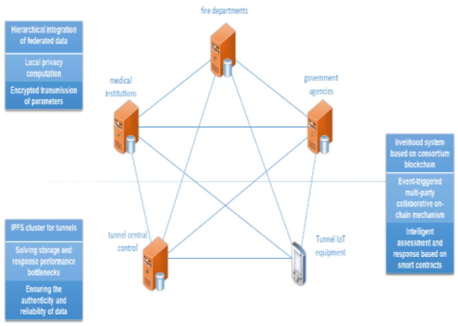


Figure 4. Overall Architecture of Data Integration

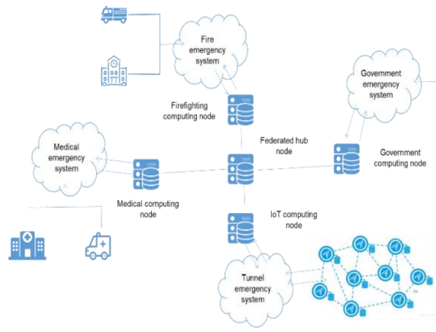


Figure 5. Data Federation Layered Integration Architecture

Data federation refers to a scheme for data sharing among multiple entities while protecting data privacy and security. It is a method for integrating multiple sources of big data in a decentralized data governance environment. To achieve effective data querying and analysis, various methods for data integration and query analysis are used to integrate distributed data sets located in different places into a unified data view. In data federation, each entity's data sets remain isolated and not visible to others. For example, patient data held by hospitals should not be visible to tunnel management, and tunnel traffic data should not be visible to hospitals. Therefore, this project proposes using data federation to solve the problem of data availability and invisibility. The goal of data federation is to improve data availability while protecting data privacy and confidentiality. It allows different entities to share data without centralizing it in one place. Data federation is often closely integrated with federated learning technology and uses secure multi-party computation, encryption technology, data sharing protocols, etc. to ensure data privacy and security.

The data federation in this project belongs to vertical federation of relational data. The essence of vertical federation is combining different feature data, which is suitable for scenarios with overlapping users but fewer overlapping features. For example, through ambulance information passing through the tunnel, they are all ambulance information and have a unique license plate identifier (same sample). However, hospitals have information about the vehicle and patient conditions, while tunnel management has information about vehicle entry and exit, and emergency medical services have information about vehicle and driver information (different features). Therefore, the three data entities have the same user information, but the intersection of their user features is relatively small. Vertical federation learning is to aggregate these different features in an encrypted state to enhance the model's federated learning capabilities.

The methods used to achieve data federation are not discussed in this article, and there will be a dedicated article after the project is completed to elaborate on it. This article only discusses how federated computing contributes to the function of the smart tunnel system. Taking an ambulance passing through the tunnel as an example, data federation can connect hospital data, local medical emergency system data, and tunnel management system data through certain methods to obtain data query results, obtain emergency vehicle information, and determine the level of medical assistance. It opens up a green channel for data including emergency assistance, vehicle location, preliminary diagnosis (judgment), and traffic congestion feedback, triggering data collection and push tasks in real-time. The real-time situation data is pushed to locally deployed computing nodes, and the tunnel civil scenario vehicle navigation model is launched.

Between local computing nodes of medical, firefighting institutions, government departments, tunnels, and other different types of entities, the triggering of analysis tasks and the transmission of model parameters are coordinated through the federation hub node. The federation hub node itself does not perform model calculations but interacts with smart contracts on the alliance chain and various aggregation nodes to trigger local model calculations, encrypt parameter transmission between entities, and synchronize result data. This helps the alliance chain achieve privacy computation and encrypted communication.

3.3 Implementation of Real-Time Intelligent Vehicle Navigation

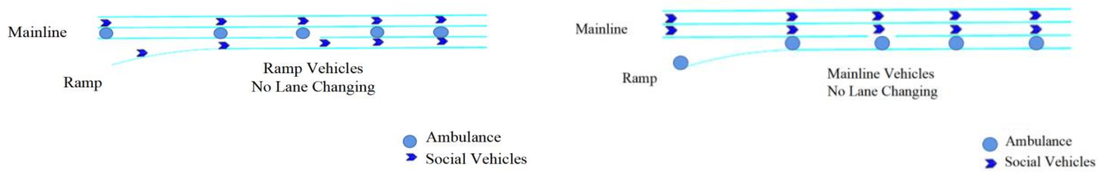
Through the IoT platform at the tunnel end and the two-phase work of federated data layered integration, the perception function and data integration of the livelihood system have been initially achieved. In this section, we mainly discuss how to realize the ambulance perception, decision-making, and control parts of the livelihood system through the control method.

The livelihood system comprises three main functions: perception, decision-making, and control. The perception function serves to connect the livelihood system with the ambulance and information exchange systems in the tunnel, enabling it to receive emergency passage demands promptly. The decision-making function involves the system analyzing and judging the federated data module's received information and activating the response plan to open up a green channel if conditions are met. The control function generates broadcasts, large-screen information, and advance warning alerts for emergency avoidance scenarios and opens up green channels for ambulances, providing necessary navigation.

In this part, for the control phase of opening up green channels for ambulances and navigation, two traffic organization paths have been designed based on specific circumstances.

The first is the Green channel traffic organization (mainline entry): Ambulances enter the tunnel through the mainline, and social vehicles are prohibited from using the lanes in the mainline (control strategy: the variable message sign at the entrance of the tunnel shows "No Entry"). Vehicles entering the tunnel from the ramp are prohibited from changing lanes (control strategy: the variable message sign on the ramp shows "Stay in Lane and Prohibited from Changing Lanes"), while supporting broadcasts inform and CCTV systems monitor the status of green channel vehicles. This lane setting will reducethe mainline capacity to some extent, but the ramp is hardly affected, showed as the Figure 6(a).

The second is Green channel traffic organization (entry from the ramp): Ambulances enter the tunnel from the ramp, and social vehicles are prohibited from using the lanes on the mainline (control strategy: "No Entry" is displayed on the variable message sign at the entrance of the tunnel). Vehicles entering the tunnel from the ramp are prohibited from changing lanes (control strategy: "Stay in Lane and Prohibited from Changing Lanes" is shown on the variable message sign on the ramp), while corresponding broadcasts are made for information dissemination, and the CCTV system is employed to monitor the status of green channel vehicles. This lane setting may decrease the capacity of the ramp to some extent while having hardly any impact on the mainline, showed as the Figure 6(b).



(a) The Control Strategy of Ambulances Entering the Tunnel Through the Mainline

(b) The Control Strategy of Ambulances Entering the Tunnel Through the Ramp

Figure 6. The Control Strategy of Ambulances Entering the Tunnel

3.4 Enabling Efficient Ambulance Emergency Response

By integrating an IoT platform at the end of the tunnel and leveraging a multi-phase process of federated data layering and real-time vehicle navigation, the Smart Tunnel Livelihood System has successfully achieved its sensing function and integrated data effectively. This section will primarily delve into the system's operations and illustrate the process in detail.

The Smart Tunnel Livelihood System comprises three key components: sensing, decision-making, and control. The sensing function mainly entails bridging the Smart Tunnel Livelihood System with the ambulance system and the information exchange system of various tunnel systems to receive emergency passage requests. The decision-making function focuses on conducting comprehensive analysis and judgment of the information gathered from the federated data module and activating the response plan to grant access to a green channel if the conditions are met. Lastly, the control function involves generating broadcasts, large-screen information, and advance warning alerts for emergency avoidance situations, opening up green channels for ambulances, and providing necessary navigation assistance, showed in Figure 7.

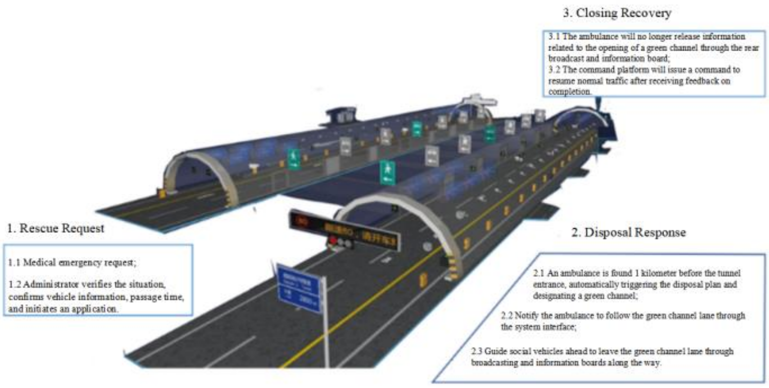


Figure 7. The Smart Tunnel Livelihood System

During an emergency, citizens call medical institutions for assistance, which evaluate the urgency and request green channel access for ambulances. Via the integration of real-time tunnel data and government data into the civil service system, relevant information such as vehicle details and passage times are fed into the system. Response plans are then distributed to the relevant parties.

During the response stage, following the instructions of the response plans, social vehicles are guided through the green channel using information displays and announcements. Required vehicles are discovered before entering the tunnel, and traffic control and green channel opening work is coordinated with tunnel management and transport departments as needed to facilitate ambulance passage.

During the recovery stage, after the ambulance has passed through the green channel, relevant broadcasts and large screen guides are turned off, and information is fed back to the command and dispatch platform. The platform confirms the recovery of normal traffic flow and cancels the green channel.

The overall smart tunnel livelihood system solution is achieved through three technological pathways. Firstly, an IoT platform based on edge computing is established within the tunnel, enabling efficient data transmission and interconnection between IoT devices. This eliminates data silos caused by independent communication and control systems within the tunnel and forms an efficient IoT platform. Secondly, a layered integration system based on federated data enables data sharing and collaborative analysis between different urban management and governing authorities. This enhances our understanding of the traffic situation and real-time emergency needs within the tunnel. It also solves issues relating to multi-location data sharing, privacy protection, and real-time data analysis. Thirdly, a real-time emergency vehicle perception and navigation system is established, which enables the timely opening of virtual green channels based on visual equipment at the tunnel entrance and various scenarios in response to emergency medical and civil needs. This helps to prevent urban tunnel congestion and traffic chaos, creating an efficient, collaborative, and safe intelligent vehicle navigation system. This realizes the closed-loop application of the smart tunnel livelihood system. This system represents a cutting-edge approach to emergency response, enabling efficient and real-time communication between emergency responders, government authorities, and medical institutions, streamlining traffic flow, and allowing emergency vehicles to reach those in need quickly and safely.

The Smart Tunnel Livelihood System's advanced technological pathways ensure its effectiveness, with the IoT platform based on edge computing creating an efficient data transmission system within the tunnel. The layered integration system based on federated data ensures seamless collaboration, comprehensive understanding, privacy protection, and real-time data analysis for the traffic situation and emergency needs within the tunnel. Lastly, the real-time emergency vehicle perception and navigation system enables the timely identification of required vehicles and dynamic opening of virtual green channels to prevent urban tunnel congestion and traffic chaos.

The Smart Tunnel Livelihood System represents a milestone in intelligent vehicle navigation systems and will serve as a model for other emergency response solutions worldwide. As cities continue to grow and demand for efficient emergency services increase, innovative solutions such as this will prove essential in ensuring the safety and wellbeing of citizens. It shows the achievable example of smart cities.

4. CONCLUSION

The creation of smart cities is faced with numerous challenges, particularly upgrading existing systems and devices for smart city construction and raising citizen awareness and appreciation of the significance of smart city development. This paper uses the Smart Tunnel Livelihood System as a case study and proposes innovative solutions for urban redevelopment and expanding its current status.

The Smart Tunnel Livelihood System constitutes a key component of smart city construction, encompassing both urban transportation and livelihood sectors. By creating urban smart tunnels connecting to healthcare centers and establishing an IoT end-system for integrating perception and control, real-time monitoring of rescue vehicles and barrier-free access to green channels can be achieved, improving the efficiency and quality of urban emergency response. Moreover, by formulating a multi-layered, data federated management and evaluation strategy for smart city governance, we can achieve transparent and seamless data availabilities and integration relationships between the city tunnel, hospitals, and medical emergency departments, leading to significant improvements in urban rescue operations and data security. The intelligent real-time ambulance green navigation system provides no-blockage passage solutions for the city tunnel using diverse scenario choices. The design and implementation of this entire solution represent a valuable attempt by the author's team in smart city construction, management, and operation, though challenges remain.

The potential of smart city construction and its innovations is far-reaching, offering a glimpse into the harmonious fusion of technology and society. The realization of these values requires a collaborative effort among all stakeholders, dedicated to the greater good of the community. To this end, we venture forth with boundless energy and enthusiasm, committed to shaping a world that transcends the limits of the present, thereby securing a brighter, smarter, and more dynamic future for all.

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