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CYBER-PHYSICAL-SOCIAL SYSTEM IN JINAN TRAFFIC SYSTEM: EXPLORING NEW POSSIBILITIES FOR TRAFFIC

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Abstract. This paper focuses on the application of CPSS (cyber-physical-social systems) in Jinan's transport system. Firstly, it introduces the current situation of Jinan traffic system and the concept of CPSS, and then describes its application in Jinan intelligent traffic, discusses the future direction of technical architecture development, analyses the challenges and looks forward to the future.

Keywords: CPSS, traffic system, intelligent transport systems, architecture CPSS

РЕАЛИЗАЦИЯ КОНЦЕПЦИИ КИБЕР-ФИЗИКО-СОЦИАЛЬНОЙ СИТЕМЫ В Г. ЦЗИНАНЬ (КНР): ИСЛЛЕДОВАНИЕ НОВЫХ ВОЗМОЖНОСТЕЙ УПРАВЛЕНИЯ ДОРОЖНЫМ ДВИЖЕНИЕМ

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Аннотация. В данной статье приводится пример реализации приложений CPSS (кибер-физико-социальной системы) в транспортной системе города Цзинань (КНР). Рассматривается понятие CPSS и текущее состояние реализации данной системе в г. Цзинань. Также определен вектор будущего развития приложений в транспортной отрасли, проведен анализ основных вызовов и возможностей системы CPSS.

Ключевые слова: CPSS, транспортная система, интеллектуальные транспортные системы, архитектура CPSS.

With the acceleration of urbanization, traffic congestion and inefficient travelling have become challenges for many cities. Jinan, as an important regional center city, its traffic development has attracted much attention. In recent years, Jinan has been vigorously promoting the construction of transport infrastructure, and has built a high-speed road network of "two rings, one link and sixteen shoots", with a total highway mileage of 18,456 kilometers, including 890 kilometers of motorways; the construction of a "metre-shaped" high-speed rail network is also accelerating, with a mileage of 446 kilometers. The "metre-shaped" high-speed railway network is also under

accelerated construction, with a mileage of 446 kilometers [1-3]. The city metro has 3 lines in operation and 6 lines under construction, and the public transport continues to be optimized (Fig.1). However, the problems of high traffic flow in morning and evening peaks and obvious commuting pressure still exist.

Cyber-Physical-Social Systems (CPSS) offer a transformative approach to addressing urban traffic challenges. CPSS modeling organically integrates physical infrastructure (roads, vehicles, sensors), information systems (data analytics, AI algorithms), and social factors (travel demand, user behavior) to create a holistic, adaptive traffic management framework. This integration enables real-time monitoring, intelligent resource allocation, personalized services, and ultimately, improved efficiency and resilience within Jinan's transportation network [4].

Jinan has implemented an L3-level intelligent networked bus line, demonstrating the potential of autonomous driving technology in public transportation such as bus line 1, Yanshan Xinju BRT station, which realizes autonomous overtaking, obstacle avoidance and other functions of buses, and serves more than 2,300 trips cumulatively. This achievement not only improves the safety and punctuality of bus travel, but also brings passengers a more comfortable travelling experience, demonstrating the feasibility and advantages of Intelligent Network Connected Technology in the field of public transport.

A total of 162 kilometers of Intelligent Networked Test Roads were constructed and the digital transformation of 52 intersections was completed, providing strong support for the verification of autonomous driving technology. By arranging various types of sensors and communication devices on the test roads, information interaction between vehicles and road infrastructure has been realized, providing abundant data for the R&D and optimization of autonomous driving technology.

Building upon the foundation established by the intelligent networked test roads, Jinan has extended these CPSS principles to broader applications within its transportation network. These initiatives encompass intelligent expressway management and other multi-layered approaches to optimize traffic flow and enhance safety across the city's infrastructure. The following sections highlight key deployments and future directions of this integrated approach [5-7].

1. Intelligent Expressway Management

With the help of IoT and cloud computing technology, real-time monitoring of traffic flow and events on the Shanghai-Chongqing Expressway and other sections of the highway has achieved scheduling optimization and emergency response. For instance, real-time data from the Shanghai-Chongqing Expressway is analyzed to predict potential congestion hotspots. This information is then used to dynamically adjust traffic signal timings on arterial roads leading to the expressway, proactively managing traffic flow and preventing bottlenecks before they occur. This proactive approach not only reduces travel times for commuters but also minimizes the risk of accidents caused by sudden congestion, contributing to a safer and more efficient transportation network overall. The reduction in idling vehicles also leads to lower emissions, aligning with Jinan's sustainability goals.

Physical Layer: This system relies on an extensive network of sensors embedded in the expressway, cameras providing visual data of traffic conditions, and Roadside

Units (RSUs) facilitating communication with connected vehicles. These components form the foundation for real-time data collection.

Information Layer: The raw data gathered by the physical layer is transmitted to a cloud-based platform where it is processed and analyzed using advanced machine learning algorithms. These algorithms predict potential congestion hotspots and identify incidents, providing actionable insights.

Social Layer: The traffic management department utilizes the insights generated by the information layer to make informed decisions about traffic signal adjustments, incident response, and the dissemination of real-time information to drivers via mobile apps and dynamic message signs. This human element is crucial for effective management and communication within the transportation system. This dynamic process combines the physical sensing with data driven insight and active human response to alleviate congestion.

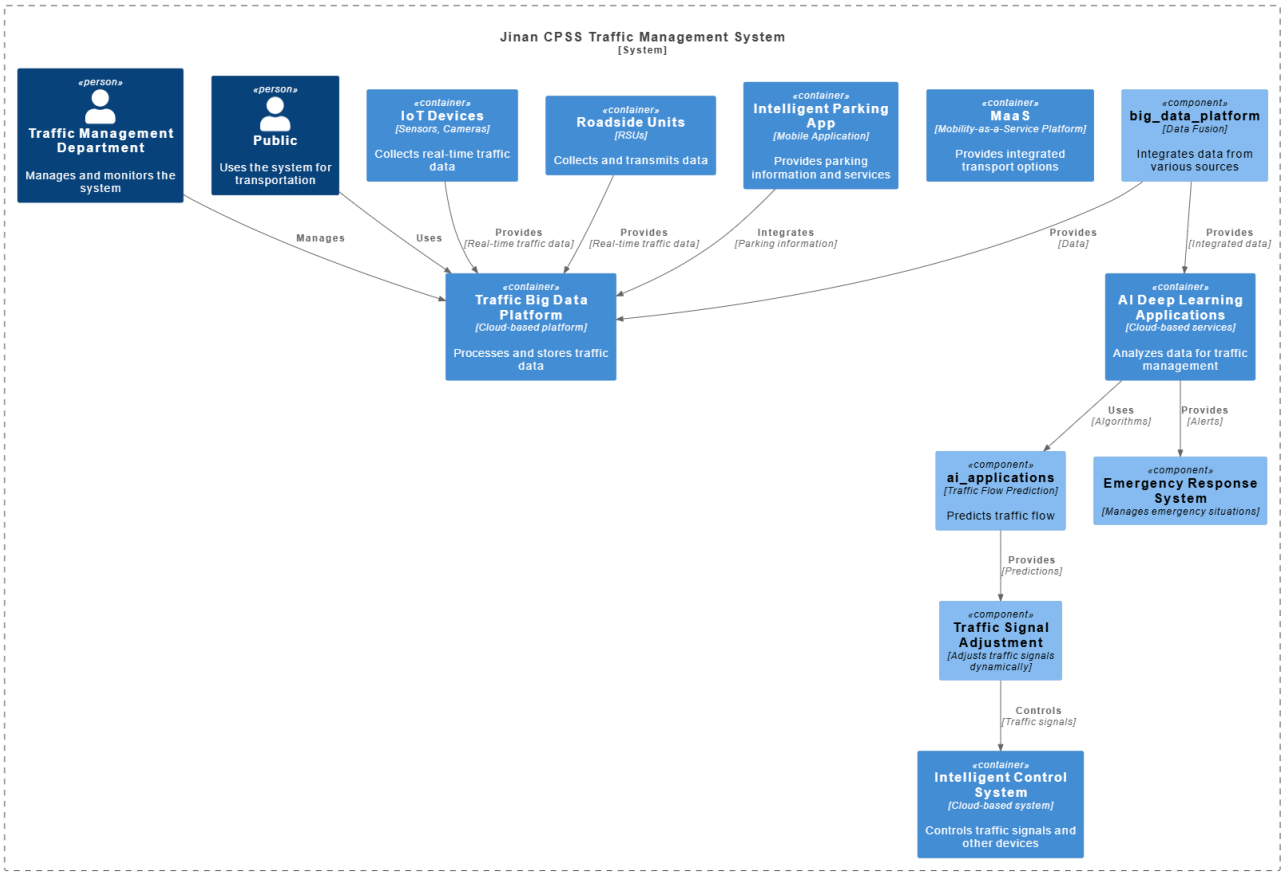

Fig. 1 – Jinan traffic management based on CPSS

2. Multi-layer synergistic development

Physical layer: continuously improve the intelligent infrastructure and promote the development of automatic driving technology. For example, intelligent street lights, intelligent traffic signs and other facilities are deployed in some key road sections to provide more accurate information guidance for vehicles.

Information layer: Relying on the traffic big data platform and AI deep learning applications to achieve data-driven decision-making. Through the analysis of massive traffic data, it predicts traffic flow trends and provides a scientific basis for traffic planning and management.

Social layer: policy support and public service synergy. Jinan has been approved as a national pilot city for the integration of vehicle, road and cloud, and has introduced relevant policies to encourage the development of intelligent transport. At the same time, it promotes intelligent parking APP, which facilitates the public to inquire about parking spaces in real time and reduces the time of looking for a car. It also introduces MaaS (Mobility-as-a-Service) mode, integrates the "rail+public+slow" network, optimises the travel experience of the public, and explores the reservation service of unmanned buses to improve the coverage rate of public transportation.

Building on current successes, Jinan's future CPSS development will focus on four key areas:

1. Intelligent Infrastructure Upgrade

Continuously promote the construction of interchange hubs for the Jibin high-speed railway and metro, so as to realise the seamless connection of "air-rail-public". For example, an intelligent guidance system will be set up in the interchange hub to facilitate passengers to quickly transfer to different modes of transport and improve travelling efficiency.

2. Full deployment of intelligent terminals

Sensors, cameras and roadside units (RSUs) are installed at key nodes such as rail stations and bus routes to build an all-area perception network. These devices can collect traffic data in real time and provide more comprehensive and accurate information for traffic management and services.

3. Information Fusion and Intelligent Decision Optimization

AI algorithm upgrade: Use reinforcement learning to dynamically adjust signal timing, combine with meteorological data to predict congestion, and improve emergency response efficiency. For example, during heavy rainfall, traffic signals of waterlogged roads are adjusted in advance to guide vehicles to avoid congested areas.

Platform synergy and integration: Integration of five platforms, such as the Transportation Big Data Centre and the Intelligent Control System for Safety Risks, to achieve cross-departmental data sharing and real-time analysis, break the data silos, and provide a more comprehensive perspective for traffic decision-making.

4. Construction of Industrial Ecology and Improvement of Regulatory Guarantee

Cultivation of industrial ecology: Attract enterprises such as Shanghai Xiantu Intelligence to land in the city, promote the application of self-driving sanitation vehicles, logistics vehicles and other scenarios, and form a closed loop of "R&D - testing - production" to promote the development of the intelligent transport industry.

Strengthening regulatory protection: Revise the Jinan Urban Public Transportation Regulations, improve the testing and operation norms of intelligent networked vehicles, and provide legal protection and normative standards for the development of intelligent transport.

Currently, Jinan CPSS application faces data quality and sharing challenges. There are inaccuracies and incompleteness in the data, and it is difficult to share data from different departments, just like a data island. For example, at morning and evening peak intersections where people and vehicles are intertwined, data collection is difficult and inaccurate, leading to bias in data-based traffic decision-making and the inability of the model to accurately predict road conditions, which seriously hinders the role of

CPSS in Jinan's traffic.

Establish a data quality checking system to facilitate the cross-sectoral flow of data, and continuously improve the model to adapt it to complex scenarios. After implementation, it is expected to make Jinan traffic decision-making more scientific and resource utilisation more efficient, alleviate traffic congestion and provide a smoother travelling experience for citizens.

CPSS provides a full chain of support from perception to decision-making for Jinan's ITS, and its core value lies in the deep integration of physical space, information space and social space. In the future, Jinan should continue to strengthen technology iteration, policy innovation and ecological construction, and gradually build a national leading "full-scene intelligent transport" demonstration city, providing a "Jinan sample" for the strategy of a strong transport nation.

The application of CPSS modelling in Jinan's traffic system has achieved certain results, and the direction of future development is clear. Despite the challenges, it is expected that the intelligent upgrading of the transport system can be achieved through reasonable strategies, which will improve the overall level of urban transport and provide strong support for the sustainable development of the city.

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