Asia-Pacific
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The 2021 APEC Innovation in Public Transportation (INPUT) Competition Report

APEC Policy Partnership for Science and Technology Innovation

October 2021

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Executive Summary

“Mobility is freedom;
mobility is happiness;
mobility is life.”
Prof C.C. Chen
INPUT Experts’ Panel Chair

The Innovation in Public Transportation (INPUT) Competition aims to contribute towards the vision for capacity building and people-to-people connectivity within the public transportation industries.

The following pages of this report present briefings on the most innovative urban public transport railway and bus network infrastructure, technology and mass transit service solutions submitted to the competition, with each receiving critical acclaim and industry commendation for the contributions that their works have made to the rapidly advancing fields of public transportation infrastructure and technology.

The works are divided according to the two competition groups of public transport focused universities and academic institutions, and public transport focused construction and operation companies, including small to medium enterprise product developers and manufacturers.

From the launch of the competition on 1 September 2020 to the deadline on 31 March 2021, the organizing committee received a total of 75 initial applications, ultimately accepting a total of 64 full entries from economies including China; Hong Kong China; Philippines; Singapore; and Thailand. 33 works were in the enterprise group and 31 in the university group.

Following review, one first prize, two second prize and three third prize works in each of the two groups were decided on through a three stage expert and public review process, as well as four excellence awards in both the enterprise and university groups. This led to a total of 20 works that were awarded, and each is detailed in the pages of this report.

The INPUT Report aligns with APEC’s strategic priorities by providing a conduit through which member economies can share urban rail mass transit knowledge and expertise, with a focus on bringing together new and innovative technologies and methodologies in the public transport industries that can be of benefit and progressively realized throughout APEC.

Cutting-edge innovations, breakthrough research, inspiring success stories and insightful examples are shared through the winning applications encapsulated in this report, which taken together can make a difference in the promotion of the development of sustainable livable cities within APEC member economies.

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Introduction

The APEC Innovation in Public Transportation (INPUT) Competition was conceived of as an initiative to bring young talent in the STEM fields together through offering the impetus and space to foster innovation and the development of new ideas, progressing public transport solutions across the Asia-Pacific Region in the process.

Established in 1989, the Asia-Pacific Economic Cooperation is an essential organization for the promotion of economic integration in the Asia-Pacific region, acting to improve regional trade and development. The APEC Policy Partnership for Scientific and Technological Innovation (PPSTI) aims to advance innovative scientific and technological cooperation and exchange, working with political, economic, industry and academic institutions to coordinate policy dialogues, recommendations and initiatives.

Its strategic objectives are to support the commercialization of innovations, enhance innovation capabilities, promote innovation cooperation among members, develop a market-led policy environment conducive to innovation, promote economic growth, promote trade and investment, and achieve social harmony and sustainable development.

Officially endorsed by APEC PPSTI, the INPUT Competition is a project of the China Ministry of Science & Technology managed in collaboration between the China Council for the Promotion of International Trade (Shanghai Sub-council) and the Chinese Academy of Sciences (Innovation Cooperation Center Bangkok).

It has been guided in the spirit of PPSTI to encourage scientific and technological innovation, focusing on a theme of "the integrated development of intelligent multi-modal public transportation". It was initiated in July 2020 with the solid backing of nine APEC member economies. The Project's Lead Economy is the People's Republic of China, and its Co-Sponsoring Economies are Chile; Hong Kong China; Indonesia; Papua New Guinea; Peru; Philippines; Thailand; and Viet Nam.

The competition itself was launched on 1 September 2020 at the leading China International Railway Conference for Urban & Intercity Transportation. The launch ceremony was attended

Industry Leaders and APEC Economy Representatives at the INPUT Competition Launch Event on 1 Sept 2020

by over 300 industry professionals offline, and more online as the call went out to join in furthering the common aims for sparking innovation of the INPUT Competition.

Through APEC's official channels, as well as through government, industry and academic networks, the call for institutional participation was communicated, precipitating expressions of interest and support from across China, South-East Asia and the Asia Pacific. Transport industry associations, government bodies and academic institutions focusing on related fields were engaged and agreed to communicate word of the competition to encourage applications from teams of young professionals and students.

Meanwhile, the search began to bring together a distinguished judging panel of industry experts from across the region to assist with the independent application review process, consisting of 22 members convened from February 2021. Together, they assessed all eligible applications submitted in the initial review process, short-listing 40 applications that then went on to the second round in April 2021 following the competition submission deadline. Short-listed works were then put through a broader review through an online voting process, open to all transport industry professionals and publicized through industry networks.

The top 20 then went through to the final round, where the core judging panel of experts, comprised of 8 members, reassessed finalist applicants for a second time in further depth. Rankings were then determined on the basis of a combined score from each of the three rounds, with one 1st prize winner, two 2nd prize winners and three 3rd prize winners selected for both the Enterprise and the University categories, in addition to four Excellence award winners each.

The INPUT Competition Launch Ceremony

All finalist teams were kept informed of the review process and all participating applicants were invited to attend the INPUT Awards Ceremony and Exchange Meeting event at the conclusion of the competition. As a result of the unprecedented challenges surrounding travel at this time, the organizing committee paid special attention towards online engagement in making preparations for this event.

The INPUT Awards Ceremony and Exchange Meeting was held to great reception at the Shanghai University of Engineering Science and Technology on 19 June 2021. Due to the ongoing global pandemic, the event was adapted into a hybrid format to allow for online attendance and participation, with all international competition applicants, participants and supporters invited to attend through the official online event platform.

Expert Panel Members, Competition Finalists and Winners, and Organizers at the Conclusion of the Event

In all, there was an audience of almost 150 attendees at the venue and roughly 500 attendees online from throughout the Asia-Pacific Region, who all witnessed the presentation of trophies and awards certificates to representatives of all the competition award winners, as well as insightful presentations from experts and enlightening presentations from some of the selected finalists, including the 1st placed prize winner from the Enterprise Group and 2nd placed prize winners from both groups.

Finalists included teams from throughout China, Hong Kong (China), the Philippines, Singapore and Thailand, the synopsis of each of the twenty finalists being given in order over the pages of this report that follows. It is hoped that the reader is able to draw as much inspiration from the varied and impressive works of public transportation innovation presented herein as the expert panel were able to during the review process.

The Main Auditorium for the INPUT Awards Ceremony

As the engaging and generative exchange meeting was able to achieve in June 2021, may this report provide the ongoing facilitative sparks necessary to encourage the development of even more innovation in public transportation among all APEC economies, using these as a foundation for the productive pursuit of cross-border collaboration on public transport infrastructure projects great and small.

Please enjoy the seeds of innovation laid out over the following pages that no doubt will drive the engines of sustainable development in APEC economies' public transport industries in the years to come.

Background

A New Model Tram outside the INPUT Launch Conference Event

Urban public transportation has a history of more than 190 years, from its inception with the appearance of the first horse-drawn public carriage in London, England in 1829. However, from the 1960s, the worsening state of traffic congestion within both developed and developing cities throughout the world has compelled economies to accelerate the development of effective urban public transportation.

Over the past 20 years, the rapid development of public transportation in China is a shining example of what can be accomplished, and within the field of urban rail transit in particular has become a shining light of achievement, demonstrating what is possible to realize with vision, innovation and dedication.

Through public transportation works throughout the Asia-Pacific region, the emergence of large numbers of talented engineers and many other industry professionals have contributed to major public transportation infrastructure and network construction, the development of new transportation technology, and to ground-breaking academic research and development in transportation related fields. Transnational cooperation on large-scale transport projects and industry knowledge exchange are becoming more frequent, with cross-industry and cross-border innovation and collaboration increasingly becoming keywords for the advancement of mass transit in the Asia-Pacific Region.

In recent years many APEC economies have continued to advance their public transportation infrastructure and mass transit system technologies. A diverse range of Asia-Pacific economies are developing bus and metropolitan railway services in their major cities. Exponential technological progress is making more possible in the field of public transport system construction, operation and service delivery, with developments like intelligent transport systems management enhancing mass transit efficiency, reliability and safety.

Singapore is now a world-renowned leader in the area of smart cities that incorporate public transportation services with many other social services with the overarching objective of improving the quality of life of its citizens through enhancing the accessibility and connectivity of services.

Thailand is embarking on a number of mega rail network projects, such as the Eastern corridor linking the capital of Bangkok to Chiang Mai and other major Thai cities in the north. Furthermore, Bangkok's Bang Sue major railway hub, now under construction, will play a very important role for Thailand’s metro mass transit systems as part of a high-speed rail network for airport links and other essential metropolitan railway services.

Advances of this kind throughout the Pacific region are being seen to result in sustainable benefits in terms of effective metro systems, improved living environments and pollution

reduction, as well as supporting greater trade, investment and better conditions for business that feed into the broader vision for the future development of APEC economies.

It is against this background the inception of the Innovation in Public Transportation (INPUT) Competition came about under the auspices of APEC and the guidance of China's Ministry of Science and Technology. What follows in this report is the culmination of a competition process that sought innovative entries that were able to demonstrate the most promising potentials for the future of public transport development from throughout the Asia-Pacific region.

Below, the works of the INPUT competition winners are summarized and then detailed further in the pages that follow.

Award Winner Synopses

Du Hongjian, Sean Chua Xin Wei, Hussain Fathah, and Manikandan Annamalai – Members of the First Prize Winning Team from the National University of Singapore

The finalists covered a broad variety of subjects within the fields of public transportation, from research into new sustainable infrastructure materials to cutting edge intelligent transport industry equipment and breakthrough technological maintenance approaches, all demonstrating a high degree of innovative thought and novel praxis.

The first prize in the university group went to a work from Singapore that looked into the feasibility of using a recycled glass and cement composite for use as a more environment friendly building material in green public transport infrastructure projects, while the first prize in the enterprise group went to a work from Shenzhen that focused on the benefits of an integrated Building Information Modeling (BIM) project management platform solution.

Of the two second prizes in the enterprise group, one from Hong Kong concentrated on the capabilities of a new intelligent information management and distribution system for high-speed trains, focused on offering a broad range of information, business and payment services to commuters on the one side while providing rail transit operators with a comprehensive information platform solution on the other. The second detailed technical research into the feasibility of improving bus line services while reducing congestion through the intelligent application of dynamic access control processes for bus lanes.

For the first of the two second prize works in the university group, again looking at aspects of bus system improvement though with a different approach centering on dynamic alteration of dispatching and routing of buses to more effectively meet varying demand during peak and off-peak times. The other second prize work from Thailand explores the specialized and sparsely researched area of the impact of using recycled asphalt in road paving on road safety, opening up a new research direction with significant ramifications for the development of more sustainable road infrastructure.

The three third prized works in the enterprise group all offered technical research that covered different aspects of urban rail transit operation, with the first detailing a highly innovative approach to rail track maintenance inspection using intelligent vision enabled special-purposed robots capable of improving track safety inspection in many ways. The second addressed the issue of integrating different kinds of train network, from urban to intercity, suburban and arterial, devising a new control system capable of bridging operational and technological differences. Finally, the third developed a new safety-oriented method of autonomous train navigation through train-to-train communication that breaks new ground.

Mr Wang Jian, Ms Cao Yuli, and Ms Cai Xiaying – Members of the Expert Committee Discuss a Winning Innovation at the INPUT Exchange Meeting

Of the three third prized works in the university group, in a similar vein to the intelligent inspection robot work the first two of these works concentrated on different approaches to the issue of railway track and equipment defect detection and prediction. The first took a software approach that used deep learning algorithms to accurately detect and assess track surface defects, while the second took a hardware approach using purpose-built sensory equipment to detect and predict track fastener defects using vision and vibration. The third work looked at the commuter side of public transportation, devising a novel process of ride evaluation that demonstrated broad applicability across public transport modes.

The range of applicants honored with runner-up awards for excellence covered even more diverse topics of inquiry, with the enterprise group finalists investigating potentials in intelligent bus operation as well as engineering designs for railway line edge computing operator data services, advanced maintenance and inspection vehicles and next generation bus driver cockpit control systems.

Similarly innovative works detailing a broad array of engineering designs and technical research were featured in the university group excellence award winners. From ingeniously designed train subway filters to a fully fledged commuter mobile application and fleet management system, intelligent risk warning and monitoring for subway tunnel construction to ecological routing strategy design for bus networks, the works summarized over the pages that follow are sure to engage and inspire anyone interested in the future potentials of public transportation.

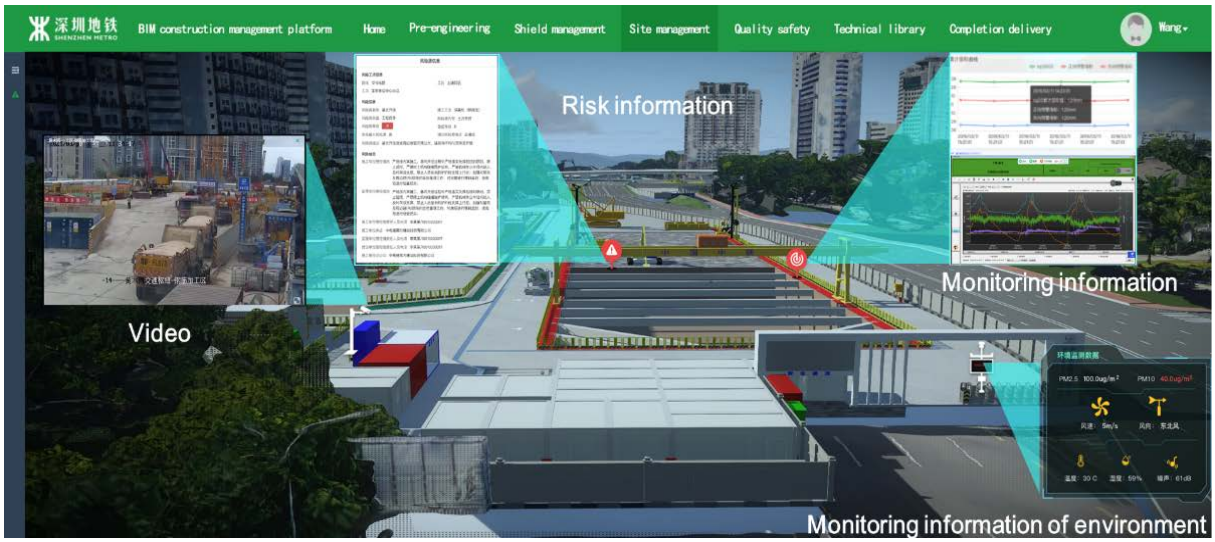
Enterprise Group

University Group

Enterprise Group – 1st Prize

"The BIM-Based Comprehensive Application Platform in the Whole Lifecycle of Urban Rail Transit in Shenzhen"

- **Shenzhen Metro Group Co. Ltd.**
- **Shenzhen Metro Construction Group Co. Ltd.**
- **Shenzhen Municipal Design & Research Institute Co. Ltd.**



Example of the BIM-Based Comprehensive Application Platform Display

Insight – Expert Commentary

"Building Information Modeling (BIM) technology is being used in rail transit design, construction and operation. The key focus of this work is in building a '1+N' comprehensive platform by starting with standards and systems, which is of great significance to advancing track development."

"This work applies BIM and other digital technologies to the entire process of urban rail transit planning and construction, and provides strong support for promoting the standardization of industry technical standards, improving construction level and project quality. It has been verified in practice and has good application prospects and value."

Inspiration – Basic Idea & Purpose

Constructing rail transit systems is the most important way to support the development of smart cities, strengthening the city skeleton and connecting public transportation in various regions.

To realize a high-tech and green metro, the Building Information Modeling (BIM) system for rail transit construction management and engineering project delivery was developed, based on the experience of Shenzhen Metro. Through incorporating BIM with "Big Data", "IoT", "GIS", "5G" and some other modalities, this work focused on building a unified BIM application and developing a BIM-based comprehensive platform using the concept of "1+N". Its overall

purpose was to establish a digital metro engineering project management system serving the entire industrial supply chain.

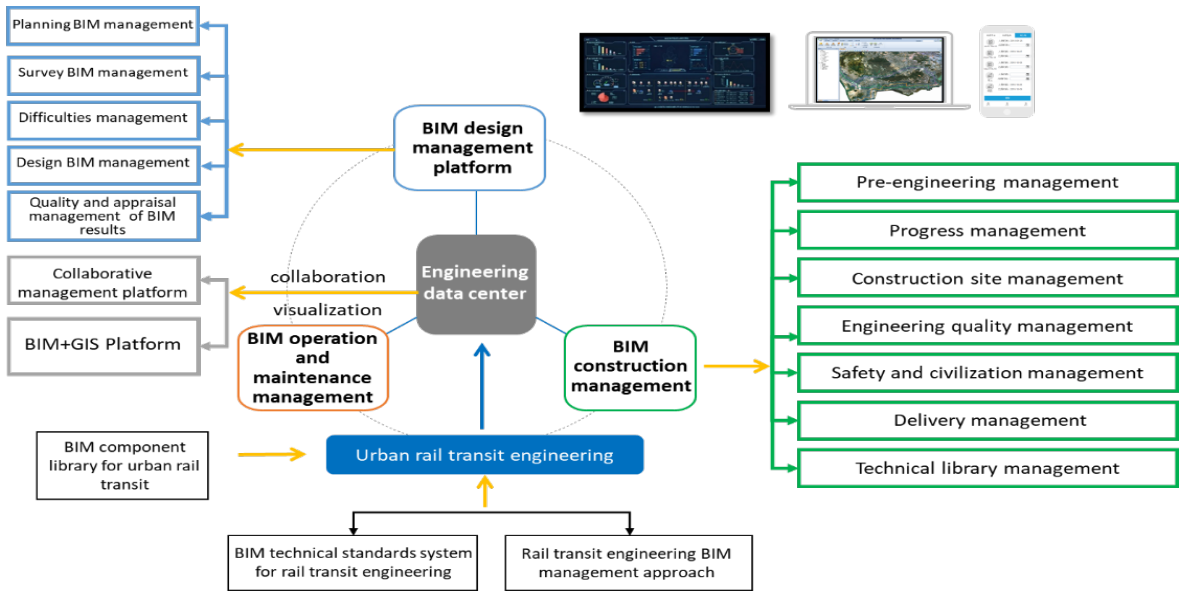
The work established a BIM technical standards system with 10 standards and numerous guidelines for rail transit engineering, including classification, modeling, application and data security, in doing so unifying the approach and data types of over 100 participating bodies. It then covered the development of a multi-dimensional structured engineering data center, integrating multi-source heterogeneous data to enable efficient data mining of rail transit project data to realize value.

The work then detailed the development of a rail transit project BIM platform for design, construction and operation, which integrated data chains between stages and solved case problems in each stage. By building a BIM+GIS visual platform, the 3D display of multi-dimensional data and data transmission was realized, and the range of network-level macro scenarios was extended.

A lightweight software engine was built to improve the processing capacity of macro and micro data, and meet the requirements of smooth rendering and rapid interaction. A multi-disciplinary component library was also developed, integrating over 12,000 parameterized component models from over 30 disciplines to avoid repeated modeling and promote modeling standardization.

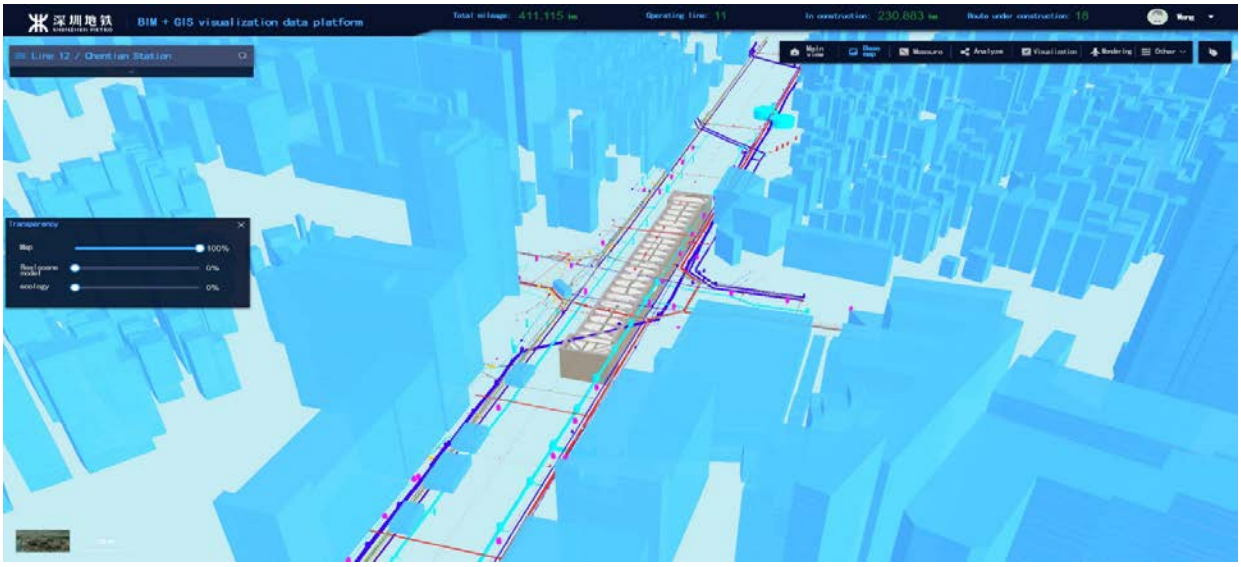
This BIM system has been utilized in 24 key projects and approximately 400 sub-projects in Shenzhen Metro, covering 235.7 km of all lines and 152 stations, consolidating large-scale digital assets and advancing the intelligence of Shenzhen Metro.

Innovations, Ingenuity & Key Technical Points



The Rail Transit BIM Application Structure

This project is a comprehensive platform based on BIM system standards and BIM management rules, including an engineering data center and 'N' business platforms – the '1+N' model. It enables BIM projects over the whole lifecycle of rail transit engineering. The data center is the base of the entire BIM platform, providing unified data for each system, avoiding data islands, data inconsistency, and other issues.



Data integration in the BIM + GIS data visualization platform

Adapting the BIM management system for rail transit, the comprehensive platform provides effective managerial oversight over an entire rail transit infrastructure construction project, according to actual project needs and ensuring project safety, quality, cost, and transparency.

Rail transit engineering involves many stakeholders including governments, operators, designers, constructors, supervisors, suppliers. Since the interface between stakeholders is intricate, it is necessary to establish a BIM management system for the implementation of guidance, supervision, inspection, review, and management over the whole process.

Key innovations include the following:

(1) Creating BIM Technical Standards for Rail Transit

The BIM technical standards system for rail transit engineering makes up for the deficiency of BIM standards in the global rail transit field and provides a basis for research and application of BIM standards in other urban rail transit projects.

(2) Initiating a BIM Collaborative Management System for Rail Transit Engineering

This work studied and put forward a BIM collaborative management system, combining the ‘lead construction unit, executive management unit, supervision unit, and other cooperating units’, which is suitable for large, complex and comprehensive projects. This system could solve common problems with data connectivity and multi-party collaboration.

(3) Developing a BIM-based Comprehensive Platform for Rail Transit

The self-developed BIM-based comprehensive platform is studied based on model resources, planning, design, construction, operation, and maintenance aspects, covering survey design, construction installation, equipment production, operating services phase. It is conducive to the sharing and exchange of data between stages while also ensuring data security.

(4) Integrating BIM and High Technology

This work studied and realized a fusion of BIM and advanced technologies such as AI, IoT, 5G and Big Data. Intelligent analysis, mobile internet, and data mining can be applied to promote coordinated, information-based and intelligent development of rail transit project construction and management.

(5) BIM Parametric Component Modeling of the Whole Field

By building a BIM component product library, more than 12,000 component models of various rail transit disciplines are integrated, covering the entire field of survey and design, construction and installation, and equipment production. The size of the component library ranks at the forefront of the rail transit field.

Overall, the platform has been widely used in construction projects in Shenzhen Metro, including more than 150 stations and hub projects, and has accumulated a massive 7TB of data. These digital assets have provided a unified data source for various business applications of rail transit. Based on data analysis, the platform effectively improves the level of digital, information-based, intelligent management, simultaneously reducing the cost of project construction, operation, and maintenance, while bringing huge economic benefits.

At present, the platform has been used by nearly 9,000 users from more than 240 enterprises. It not only standardizes the behavior and results of various units and personnel, improving project quality, but also trains groups of BIM talent and improves overall project management capability, which has many additional social benefits.

Built up through a large amount of analysis and application, the BIM-based comprehensive platform and digital assets have universality and can be applied to other urban rail transit projects. The platform also has great potential for the digital transformation and development of urban rail transit and has high impact and promotional significance. For similar engineering projects, the platform can enable the development of rail transit projects with more intelligent project design and management, while also encouraging considerable secondary socio-economic benefits.

Enterprise Group – 2nd Prize

"High-Speed Train Intelligent Management & Information System Based on New Generation Network Technology"

- **Hong Kong Productivity Council – Automotive Platforms and Application Systems R&D Centre**
- **Kam Yip (Hong Kong) Limited**
- **GuangDong Golding Mobile Multimedia Limited**

Insight – Expert Commentary

"This work is based on a new generation of 5G and MOST150 technology to develop a high-speed rail information management platform and a business travel multimedia system. It integrates the high-speed rail network with the Internet, makes full use of the characteristics of the cloud platform, and takes into account the internal network architecture and external system docking requirements for high-speed rail. It satisfies functions such as smart ticket verification, self-service ticket replenishment, train security, special services, remote monitoring and customer service systems. The work has good practical value and application prospects."

"This work is used to support the two core businesses of high-speed rail management and business travel multimedia systems. The work has good application prospects and commercial value. The application has a rigorous structure, clear expression and strong logic."

Inspiration – Basic Idea & Purpose

With the rapid development of China's high-speed trains, there is an increasing demand for high-speed Internet applications for multi-user terminals in the high-speed train environment. Because high-speed trains run at high speed across provinces and cities, the existing high-speed train network is limited by transmission speed and cannot meet the needs of launching new services. Therefore, a high-speed Internet system optimized for high-speed train shall be developed.

This product is a high-speed train intelligent management and information system based on a new generation of 5G technology and Media Oriented Systems Transport ("MOST")

technology. This system itself has the characteristics of high concurrency, capacity and can communicate in real-time. Facing the large passenger user group and high service experience requirements, this system chooses to put the entire business on the cloud platform, making full use of the characteristics of the cloud platform to connect to the internal network of the high-speed train and external ground operation center to meet the various needs and requirements of high-speed train travel scenarios. In addition, it can also be combined with intelligent face recognition technology to meet functions such as intelligent ticket verification, business service, self-service ticket purchase, travel security, and customer service, etc. This system can not only provide data services for relevant departments and improve the overall service level, but also meet the passengers' travel needs and satisfaction, providing passengers with a high-quality experience.

Innovations – Key Technical Points

The proposed MOST intelligent information management platform and business multimedia system for high-speed trains is on a cloud platform, taking into account the needs of high-speed train applications. The internal network system includes cloud server, main unit and terminals.

This product can realize smart ticket verification, passenger business services, self-service ticketing, public security services, special services, beverage ordering, remote monitoring, mobile payments, and many other customer services, taking into account all aspects of high-speed train management and passenger business travel needs.

It has been developed based on the new generation of 5G and MOST150 technology. The performance goals of 5G are high data rate, reduced latency, energy saving, cost reduction, system capacity improvement and large-scale device connection. MOST is an in-vehicle multimedia network technology used in the automotive industry. The existing MOST150 standard uses optical fiber as an information transmission medium for ultra-speed network transmission. As an in-vehicle network interface standard, MOST enables multimedia components in large capacity transportation tools (i.e. buses and high-speed trains) to communicate in high-speed transmission.

Advanced Cloud Platform Architecture

The architecture layer is based on the cloud platform and is responsible for core data processing, storage, retrieval, computing and other major functions, specifically including:

(1) Open connection of system data: establishing data production and consumption, and sharing data resources for multiple users and platforms.

(2) Cache Redis: cache data processing, which greatly improves the response speed of the system and ensures the high reliability and high availability of the cache through the cluster mode.

(3) Real-time Streaming: supporting streaming transmission and playback media.

(4) Distributed Messaging: with high throughput and high scalability for multimedia resources.

(5) Payment systems: providing support for the current main payment methods.

(6) Face recognition and storage retrieval system: providing face acquisition, storage and retrieval, and docking with the external existing system for fast and efficient recognition results.

(7) Basic data center: vehicle, equipment, resources and user rights management database.

(8) Business data center: storage, retrieval and analysis of various business data such as ticket checking, supplementary ticket and meal ordering.

(9) Media broadcasting data center: data processing for film, advertisement, monitoring and broadcasting statistics.

Networking of the Whole Train Server

The entire train requires a total station server to connect to the 2 host network servers of each carriage through 4G/5G signals. The Wi-Fi Mesh is used to form a local area network connection (some areas may not have 4G/5G signals).

Single Carriage Display Terminals Connected with MOST Networks

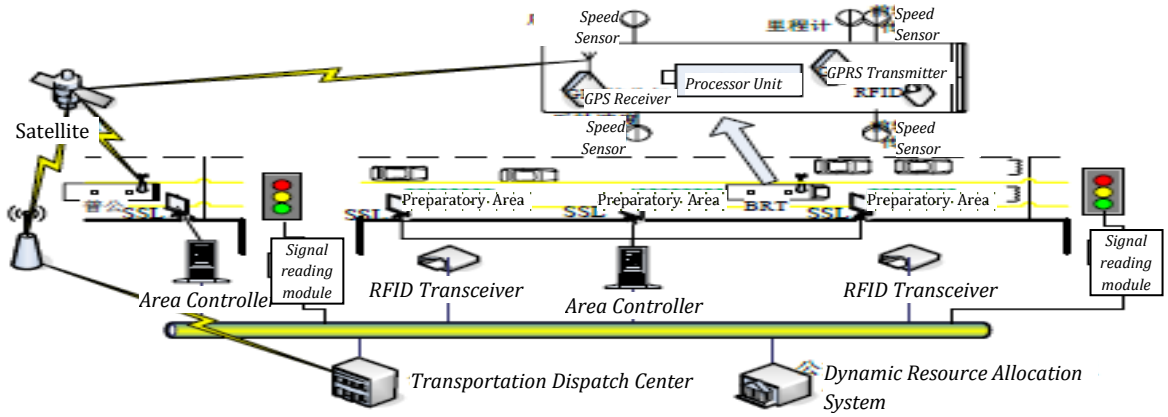
The 100 display terminals in a single car are connected to the 4-way MOST network of 2 hosts, each of which transmits HD programs at a source rate of 4MB/s, while the MOST network bandwidth is 150MB/s. Therefore, a MOST network of 2 hosts and 4 channels is used to connect 100 display terminals. Every MOST network is connected to 25 screens to ensure that there is enough bandwidth transmission.

The MOST high-speed railway optical fiber Internet system creates an ecosystem by creating platform products and combining different needs in the industrial chain. The products can cooperate with manufacturers, operating companies, advertising and media companies. In terms of services, it not only meets the needs of passengers during high-speed rail travel, but also provides passengers with high-quality experiences including interaction, consultation, discounts, free services and ticketing, thus creating more value for society with Internet thinking.

Enterprise Group – 2nd Prize

"Dynamic Access Control for Bus Lanes on Urban Corridors Based on Data Mining"

- **Shenzhen Railway Investment & Construction Group**
- **Shenzhen Municipal Design & Research Institute**



DBL Topology Diagram of Dynamic Resource Allocation Implementation

Insight – Expert Commentary

> "The research on the temporal and spatial dynamics of urban regional transportation networks and BRT dedicated road traffic flow based on the solitary wave theory proposed by this work has not been reported on before, and the argument is innovative. Although the basic theory of DBL resource allocation technology is feasible, its practical application is complex and limited. For traffic management, spare lanes and change lanes can actually increase congestion."
>
> "This work studies and discusses the issue of dedicated lanes management for buses. To realize proper priority of bus transit vehicle right-of-way is the most important aspect here, and through the scientific and effective implementation of "DBL" theory to oversee road resources, better and more comprehensive utilization can be achieved."

Inspiration – Basic Idea & Purpose

Setting a Dynamic Bus Lane (DBL) can fully ensure that public transport vehicles can be unimpeded in both peak and off-peak periods, thereby greatly improving the operating speed of buses and significantly reducing the traffic time of travelers. It is an ideal tool to rapidly increase the bus travel sharing rate. Theoretically, DBL resources should be exclusively used by specific bus lines to ensure the stability and efficiency of the public transport system and attract more urban travelers to choose public transport vehicles.

In fact, due to the severe shortage of per capita road resources, BL are usually assigned intermittently for exclusive use based on peak/off-peak. This practice does not ensure the overall operational efficiency of the bus system, because an intermittent BL system is based on the concept that each lane provides static traffic supply, which completely

ignores the dynamic interaction between vehicles and the traffic supply, an inherent nature in urban traffic systems. This impairs the operational efficiency of the public transit system.

In this work, a method of dynamic allocation of urban public transport lane resources based on data mining is proposed, and the existing BL technology is innovated and refined dynamic resource allocation is carried out. Finally, under the premise of ensuring the dynamic stability of regional traffic, the dynamic allocation of BL road resources is realized and its resource utilization is maximized. The lack of data mining on BL traffic flow and research on BL dynamic control has become a bottleneck restricting innovation of existing BL technology.

The application of DBL has the potential to maximize utilization of the scarce traffic supply resources while ensuring traffic stability in the entire road network by dynamically allocating those lanes.

Innovations – Key Technical Points

In this work, the technical innovation builds on existing Bus Lanes (BLs) and is based on in-depth analysis and data mining of urban traffic regional networks, and theoretical research to ensure that specific bus vehicles have absolute right-of-way on BLs. Also, common vehicles can be allowed to make use of the dynamic resource allocation method of BL right-of-way in a specific time and space. Thus, complete dynamic matching of the traffic load on the entire route is realized, maximizing resource utilization through dynamically allocating BL road resources on the premise of ensuring the dynamic stability of regional traffic.

This work details three major technological achievements: first, the DBL resource allocation methodology and theoretical decision-making model; second, the dynamic resource allocation technology based on BRT location information and the spatial slice and time slice method of dividing different regions according to road attributes; and third, creating a universal BL dynamic resource allocation control system and perfected implementation solution.

Key innovations include the following:

(1) Spatial-Temporal Analysis of Traffic on BL on Urban Routes

Developing a dynamic model by studying the typical ‘soliton’ phenomenon of BL traffic on urban road networks. Analyzing urban traffic dynamics and BL traffic dynamics in the spatial and temporal dimensions based on data mining with the dispersion management theory.

(2) Development of DBL Access Control Theory

By developing a DBL access control methodology based on orthogonal phase queuing theory, all vehicles could be given access to the BL during specific time and at specific locations, while the rights-of-way of designated transit vehicles are still ensured, and thus the utilization rate of BL could be greatly improved.

(3) The DBL Access Control System Effectively Improves BL Utilization Rate

The DBL access control system we developed was tested in the real world by Hangzhou Public Transport Group on appropriate BL segments for 30 days. During the test period, the system was running smoothly and the BL are used by all types of vehicles in order. Operation of BRT and regular buses was not impacted by the test, neither was the traffic on adjacent lanes.

Experiments show that this work is worthy of popularization and application, which can obtain better comprehensive utilization efficiency for BL road resources. Since this work does not rely

on the geographical features, physical models, or mathematical models of any particular city or particular transportation area, the research results apply to the transportation network of any city. The key application technology and BL dynamic resource allocation prototype system developed can be applied in large and medium-sized cities with BL.

Potential social implications of this research include the following:

1) Exploit the potential of existing roads to alleviate traffic congestion;

2) Increase the utilization of BL while benefiting other vehicles, avoiding regular vehicles blocking BRT vehicles by giving further priority to the latter, which ensures smooth operation of the BRT system;

3) Support traffic authorities to perform traffic management in a more refined way. Based on data mining, the access control methodology for DBL provides traffic police with new means of traffic management and traffic guidance;

4) The project further promotes energy saving and emission reduction from urban traffic. The pollution caused by traffic is one of the main sources of urban pollution, and the DBL with intelligent access control has the potential to alleviate congestion and reduce pollution.

5) The research and subsequent applications will benefit everyone working in or using public transport, and thus help to realize the development goal of building a harmonious society;

6) Promoting related high-tech industries, as once the DBL control system is put into production, it will drive development of the transportation IT hardware and operation industries.

Potential economic implications of this research include the following:

1) Improving traffic efficiency, reducing fuel consumption, reducing environmental governance costs, reducing operating costs of commercial vehicles, reducing pollution, and improving our living environment;

2) Reducing the construction of transportation infrastructure and reducing land use;

3) Improving traffic conditions and people’s convenience and comfort when traveling, and improving work and life efficiency.

Enterprise Group – 3rd Prize

"Quantification of Track Condition Deterioration Based on Multi-State 3D Vision Intelligent Inspection Robots"

- **Beijing MTR Corporation Limited**

Insight – Expert Commentary

> "Rail transit intelligent inspection robots can effectively replace manual inspection, which is a key development direction. This work is designed to use laser-based 3D technology to measure tracks and auxiliary rail components, and the differences over time can be quantified to detect deterioration. It is innovative, advanced and practical, and has good economic benefits and application prospects. The work is rich in content, complete in structure and strong in logic."
>
> "The use of 3D vision robot technology to detect the deterioration of rail transit proposed in this work is very innovative. It has an inspiring effect on the potentials for automation of track maintenance and rail defect detection. It has value in application and for promotion. It is hoped that it will be combined with the development of AI technology."

Inspiration – Basic Idea & Purpose

With the rapid development of urban rail transit, the shortage of equipment and maintenance professionals is increasing, and the traditional track inspection mode relying on manual labor is gradually showing many drawbacks:

(1) The normal down-time window for urban rail transit is only 3 hours, and manual inspection in two-person teams can only complete 7km of line work per window, which is inefficient and costly.

(2) Manual inspection has a high rate of missing defects, the data cannot be quantitatively captured, nor can continuous track deterioration states be predicted or analyzed.

(3) Many track failures cannot be found in a timely manner and thus develop into major hidden dangers that can affect operational safety.

To this end, this work investigates and optimizes a 3D vision-based 2D image + 3D shape visual measurement technology for intelligent inspection robots to measure the visibility status of track equipment, generate a multi-dimensional quantitative data pool based on the measurement results, develop an algorithm to quantify the track status and its deterioration trend, and carry out research on quantitative prediction of track status deterioration development. While improving the inspection efficiency, track deterioration state analysis and prediction are carried out for track faults to realize track risk control and reduce maintenance costs.

Innovations – Key Technical Points

Track condition inspection is one of the most important means to find out in time about the deterioration of metro track equipment and facilities and to ensure the safety and reliability of operation. At present, urban rail transit mainly uses manual inspection methods for line

inspection, which can no longer meet requirements of modern rail transit due to its many shortcomings. In this context, a large number of multi-state 3D vision-based intelligent inspection methods and equipment have been developed. The basic principle is to record the appearance state of the line by means of an image acquisition device and to design a corresponding pattern recognition system to analyze and process the recorded images in order to detect line defects.

Data Acquisition

The on-board track condition inspection system is designed to detect rail surface abrasions, fastener abnormalities, sleeper spalling, track plate cracks and foreign objects in the line. The detection of defects can be compared to historical data from the same location, generating analysis reports and real-time warning of defects affecting operational safety.

In the maintenance of track equipment, three dimensions of data are required: track defect data, track base data and track condition data. The track base data is the inherent parameters of the track, such as track alignment, curve length, bed form, and number of fasteners. The track condition data is the state of the track equipment at a certain time, such as gauge value, rail wave wear value, rail wear value, and track quality index (TQI). In this project the track defect data is obtained by means of a rail inspection vehicle.

Deterioration Algorithm Development

There are two types of trend in detection data, those that are cyclical, and those that are random or non-periodic. An anomaly detection algorithm needs to be able to handle both. The following describes the three main algorithms applied in this project:

(1) Dynamic Thresholds – The dynamic threshold is set by referring to the maximum and minimum values over time and then taking the averages of both to reduce the number of missed events.

(2) Long-Term Chain – This algorithm uses a curve to fit to a trend over a longer period. If new data breaks the trend and makes the curve unsmooth, then an anomaly is detected.

(3) Chain – In order to take periodicity into account, a static threshold approach over a cyclical time period is considered to determine if the detection value is abnormal.

To accurately determine anomalies or even predict the time of failure, a combination of multiple dimensions can be used to make a judgement, combining the three algorithms above.

The data validation shows that the method adopted in this project is reasonable and feasible, and can achieve quantitative prediction of track condition deterioration, which can provide reference for related research. The next stage would be to combine quantitative data and develop equipment evaluation criteria based on experience and relevant specifications, to achieve point condition evaluation and zone quantitative evaluation of continuous use equipment, and to achieve optimal condition maintenance by virtue of these evaluation results.

Enterprise Group – 3rd Prize

"Integration Research Based on Multi-Level Rail Transit Train Control Systems"

- **China Railway Shanghai Design Institute Group**
- **CASCO**

Automated Turn-Back Interval Test of Two Urban Trains at Shanghai Hongqiao Station

Insight – Expert Commentary

> "This work researches and designs a suburban railway train control system in accordance with the requirements of the "four networks", and better integrates the characteristics of the China Train Control System (CTCS) and the Communication-based Mobile Blocking System (CBTC). It has the basic conditions for interconnection with large railways and urban rail, and has a certain degree of innovation, practicability, and application prospects."
>
> "Based on the current signal function of municipal railways, this work proposes the compatible development of the CTCS and CBTC signal systems to meet the passenger flow and encrypted departure time and division requirements, which is important for improving the service level at the city area limits."

Inspiration – Basic Idea & Purpose

At present, rail transit can be divided into different levels, such as arterial railways, intercity railways, suburban railways, and urban rail transit to meet the different needs of people. However, key differences have arisen due to their different service functions and relatively independent development histories. As a rail transit system that is currently being vigorously developed, suburban railways play a role as a connective system with functional interoperability characteristics of arterial railways, intercity railways and urban rail transit. Requirements for the integrated development of the "four networks" – arterial rail, intercity rail, suburban rail and metropolitan rail – have been proposed in China, and research on new systems and new standards is encouraged.

The train control system is the key to realizing integrated development of different forms of rail transit. Therefore, research based on the integration of multi-level rail transit train control system is essential to achieve the "four networks integration".

Taking full reference to the construction cases and experiences of similar projects at home and abroad, based on the existing mature train control system and guided by the functional requirements, a set of fully functional, concise and highly integrated train control systems is constructed to meet the requirements of interoperability and public transport operation, and to be compatible with the requirements of CTCS and CBTC systems.

Although CTCS has good experience in standardization, networking, compatibility, interoperability and other aspects, there exists a big gap between CTCS and CBTC on driving density, automation level, and intelligence level. The CBTC system can realize functions such as high-density, fully automated unmanned driving, real-time adjustment of train plans, and automatic turn back, but it has obvious shortcomings in standardization, compatibility of different system supplier systems, and interoperability.

Innovations – Key Technical Points

The innovations of the Suburban Railway Train Control System in this study are mainly reflected in the following aspects:

1) Meets interoperability operation demands of the different train control systems, greatly improving efficiency, automation and intelligence levels of suburban railway transportation.
2) Compatible with CTCS and CBTC systems, truly achieving the goal of four networks integration.
3) Enables an automatic switch between the different systems.

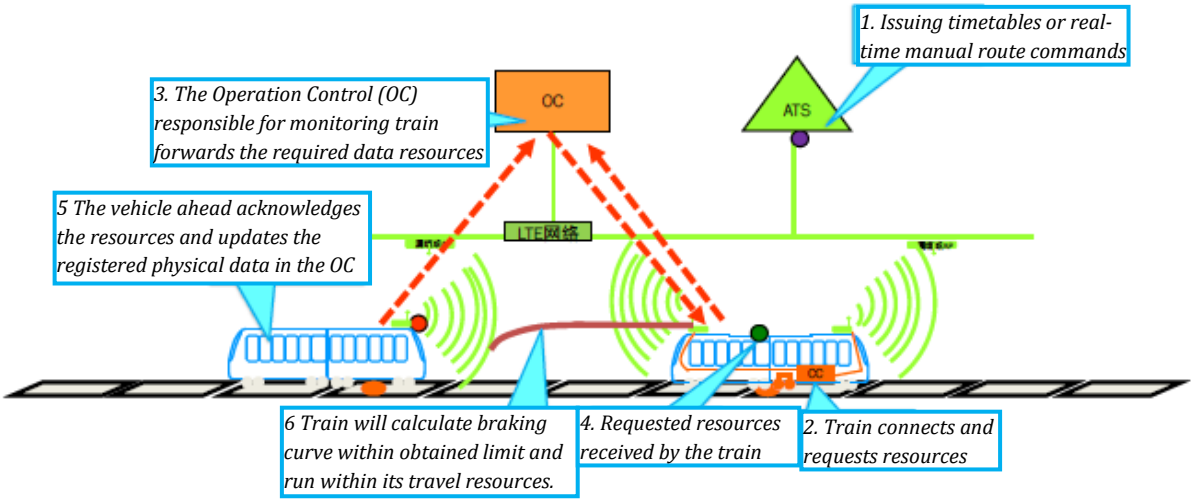
The main technical achievements of the research include:

1) Realizing the goal of a 2 minute minimum driving interval and 30 pairs per hour.
2) Realizing the requirements of automatic operation level GoA3 and above.
3) Realizing the unmanned automatic turn-back function, with turn-back capability meeting the requirement of main line passing.
4) Effectively shorting the true length of the strands of the wiring stations in the city (suburban), from 400 meters required by CTCS to 240 meters, greatly reducing the amount of civil works and demolition works, reducing station energy consumption, reducing operators, and improving operations efficiency.
5) A technologically advanced suburban railway train control system as the first research in China was constructed to fill the gaps in the domestic suburban train control system.

Enterprise Group – 3rd Prize

"Train-to-Train Communication Based on a 'Train Autonomous Circumambulation System' — TACS"

- **Qingdao Metro Group**
- **Shanghai Fuxin Intelligent Transportation Solutions**
- **Qingdao Fuxin Urban Rail Technology**



Process Schematic of Train-to-Train Communication using TACS

Insight – Expert Commentary

"On the basis of the mature FAO technology, an autonomous train operation system based on vehicle-to-vehicle communication is further adopted. This work further improves the level of intelligence and convenience of the urban rail transit train control system. It has been used in Qingdao Metro and is worth recommending."

"With the advancement of science and technology, vehicle-to-vehicle communication has become a key development trend in urban rail transit signal systems. Professional manufacturers have invested a lot of energy in the research of next generation signal technology. In this project, joint research is conducted to reshape the system architecture, optimize operation and control modes, improve scalability and redundancy functions, and create a safe, efficient and reliable autonomous signal control system that meets operational needs. It has good market application value and promotion significance."

Inspiration – Basic Idea & Purpose

The Train Autonomous Circumambulation System (TACS for short) is a new generation train control technology that places the train as the core of a deep integration between vehicle and signaling system. Compared with the traditional train control systems, TACS achieves technical breakthroughs of vehicle and train control, and its technical advantages are prominent. It will be applied on Qingdao Metro Line 6.

TACS is based on train-to-train data communication that deeply integrates the traditional train-ground two-layer distributed train control system with an on-board network, traction and braking system, taking the on-board control platform as its core to realize self-routing, self-protection and self-operation, so as to realize full autonomous control.

Compared with the traditional CBTC system, TACS equipment is simpler, the structure is flatter, the systems are highly integrated, and the information interaction between trains is direct. The system provides a flexible and diverse traffic organization mode, which is helpful to deal with various faults and emergencies. In addition, TACS is a new option for the upgrade of existing lines, and can further reduce the operation and maintenance cost of the system life cycle. TACS overcomes the bottleneck of traditional train control system, takes the principle of ensuring traffic safety and improving operation efficiency, shortens the period of construction and reduces life-cycle construction and maintenance cost. In all, this work is of great practical significance to ensure the healthy and sustainable development of urban rail transit around the world.

Innovations – Key Technical Points

The train Operation Control (OC) system is highly integrated with on-board network control, traction and braking systems. Ethernet is used to build control network covering all intelligent devices, which optimizes on-board network layout, improves train performance and reliability, and is conducive to train management, control and maintenance. “Train-to-train" wireless networks are used to track and correlate train operation status, and intelligent driving control technology and traction braking equipment are adopted to realize autonomous operation.

The traditional CBTC trackside interlocking and zone control equipment are integrated into the on-board control platform. Through "train-to-train" communication, train self-routing and self-protection are realized. Trackside equipment is reduced, subsystem interface is optimized and real-time performance is improved, effectively reducing construction requirements and cost.

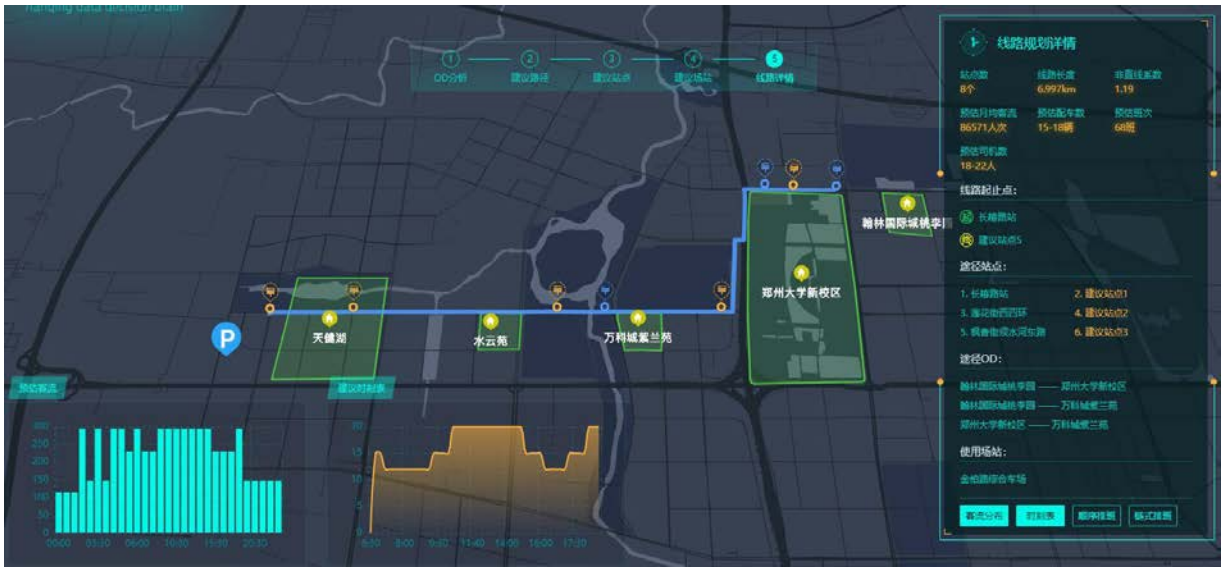
Through the normalization and standardization of system composition, equipment interface, control logic and communication protocol, the train under TACS can realize interoperation between lines in a self-organizing mode.

TACS, as a new generation of urban rail transit products with independent innovation, is a product that can lead the development trend of rail transit in the future. TACS can improve operation efficiency, reduce the operation and maintenance costs, and bring about reform of rail line planning and construction, while meeting the needs of operators and catalyzing the transformation of the rail transit equipment manufacturing industry.

Enterprise Group – Excellence Award

“The Data Decision Brain System”

- **Zhengzhou Tiamaes Technology**



Automatic Generation of a New Bus Line

Insight – Expert Commentary

> “Urban buses transport tens of millions to their destinations every day. How to make enterprises effective, orderly, and precise, requires the smart brains of public transportation. The work provides decision support for the optimal configuration of the public transport system.”
>
> “This work effectively integrates data resources from the perspectives of operators and managers, as well as multiple different scenarios. Through the transit “Data Brain", a new generation of bus intelligence is perceivable.”

Inspiration – Basic Idea & Purpose

This work is computer software for the public transportation field that provides auxiliary decision-making functions for the fleet operation and management team; the product can also be used as a basic platform for integrating bus data resources and integrating bus business scenarios.

In the daily operation of public bus routes, the ‘Data Decision Brain System’ is a resource integration platform for public transportation data, providing interfaces for collecting and summarizing various historical and real-time data on vehicles, drivers, and overall operations, with visualization capabilities for various types of data and platform support for subsequent bus data mining.

In terms of public transportation resource allocation, the work is an auxiliary decision-making platform that integrates scenarios and data on operations, management and urban planning to provide decision support for the optimal temporal-spatial configuration of public transportation resources.

Temporally, based on historical bus operation data, it uses heuristics, deep learning and other algorithms to customize scientific operation plans for route operations. Spatially, based on historical configuration information of bus resources, combined with cellular signaling, travel, geographic and other available data, it uses network analysis, path planning and other algorithms to provide solutions and program references for new openings and adjustments of lines.

Innovations – Key Technical Points

The Data Decision Brain System integrates data resources to help upgrade public transport, solving problems of data isolation and barriers while providing visualization and analysis functions. The platform intuitively understands the public transport distribution of drivers, vehicles, supplies and other resources, while monitoring public transport route completion, operational changes, real-time passenger flows and changes. The work also features display and analysis functions of commuter travel characteristics and patterns, road conditions and bus to subway connections.

The work optimizes the allocation of transportation resources for bus line networks based on the evaluation of changes in passenger flow, route coverage and travel demand to give suggestions for line adjustment, development and new construction. In the formulation of operational plans, optimizing bus schedules and turnaround times on time-division routes, monitoring changes in passenger flow, the platform uses whole-network scheduling to optimize route vehicle allocation, advanced driver scheduling technology to improve driver labor efficiency and reduce labor intensity, and optimizes resource allocation of drivers to save vehicles, drivers and costs, and improve the economic benefits of bus network operators.

With the ongoing informatization of the public transportation industry, integrating data resources, revitalizing data assets, optimizing process management, and improving travel experience have become the key concerns of public transport network operators. The work provides process reengineering to help in the management upgrade of bus network operators.

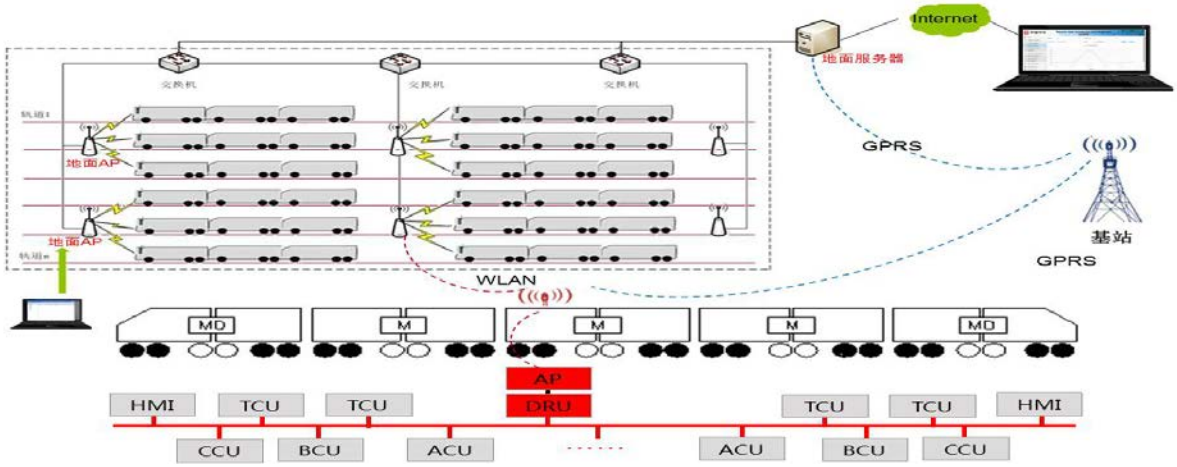
Bus line extensions, new routes, partial coverage, line abolishment and splitting are the most frequently-used scenarios in the optimization of urban public transport networks. With guideline-improvement urban public transport network optimization on a case by case basis works in practice.

New technological advances in Geometric Information Science (GIS), especially in knowledge graph mining of spatial data, mobile signaling data, and bus operation data, is adopted and used in the Data Decision Brain System. This work is a solution that establishes a bus transit network brain based on the right data, science, methodology and algorithms in this area.

Enterprise Group – Excellence Award

"Rail Transit Vehicle Data Service System Based on Multi-Standard Communication & Edge Computing"

⊙ **CRRC Dalian Electric Traction R&D Center**



Schematic Diagram of Vehicle Data Communication

Insight – Expert Commentary

"Vehicles are the key to rail transit operations. This work is based on a data service system developed to meet the needs of rail transit vehicle operation and maintenance data services. It has a positive effect on improving operation and maintenance capabilities and efficiency."

"Based on multi-standard communication and edge computing technology, this work supports real-time transmission and collection of vehicle working data, and solves the current urban rail transit vehicle data collection time lag. It effectively improves the level of operation and maintenance management through a greater supporting role for intelligent vehicle management."

Inspiration – Basic Idea & Purpose

With the rapid development and popularization of Big Data and Artificial Intelligence (AI) technology, related technical functions such as fault prediction based on rail transit vehicle operation and maintenance status data continue to mature.

In order to meet the data service needs of rail transit vehicle operators for vehicle operation and maintenance work, this work develops a data service system based on multi-standard communication and edge computing consisting of vehicle-mounted and ground equipment.

The vehicle-mounted equipment is comprised of a wireless communication unit and a data acquisition and processing unit. The wireless communication unit has signal status monitoring and feedback functions and Ethernet communication controls, enabling vehicle data transmission via 5G/4G, WLAN and satellite. The data acquisition and processing unit has MVB , TRDP, CAN, HDLC, WorldFip and other vehicle control bus network access functions,

high-speed status monitoring, command and control, and high-frequency full-time data recording functionality.

This unit is an edge computing node that through real-time data analysis can accurately determine key vehicle operation and maintenance states, transmitting this to the ground in real time at high speed.

The ground supporting data control center receives real-time data related to vehicle state, and uses AI technology to determine a health and failure prediction assessment for rail transit vehicles. It provides users with an efficient and fast man-machine interface to realize data display, early warning, alarm and other functions.

Innovations – Key Technical Points

This work includes the following technical innovations:

(1) Integrates multi-standard data bus communication protocols such as MVB, TRDP, CAN, HDLC, and WorldFip, to meet data communication performance requirements for rail transit vehicles.

(2) The data acquisition terminal combines multiple redundancy measures for bus, equipment, and signals with a control redundancy algorithm to ensure data accuracy.

(3) The data transmission terminal makes use of technologies such as network tunnels, 128-bit encryption algorithms, firewall/VPN, encryption locks, authority management, security authentication, and real-time clocks to fully ensure data security.

(4) Support for 5G/4G, WLAN, satellite and other multi-standard wireless standards, as well as support for multiple transmission technologies such as data aggregation, interrupted transmission, and lost connection retransmission to ensure high speed data transmission.

(5) Applies edge computing to accurately determine the state and related data of key operation and maintenance indicators, reducing the amount of invalid data transmission when the vehicle is in operation, and improving system response speed and efficiency.

(6) Multi-pass data display, early warning, and alarm, providing users with efficient and fast man-machine interface, and strong system usability.

In terms of edge computing technology, this work can realize high-speed analysis of data during vehicle operation, proactively determining the state of focus of vehicle operation and maintenance. Time period data is sent to the ground, which greatly reduces the cost of data transmission. Due to the focus on state data that clearly reflects the degradation of the various subsystems of vehicles, efficiency and accuracy of health prediction models are greatly improved.

In terms of wireless data transmission technology, this work realizes the intelligent judgment and high-speed switching of data transmission channels, which guarantees stable data transmission in any communication environment. The device compares signal status of cellular network providers and prioritizes channel selection or sends by satellite when cellular coverage is abnormal. In the warehouse or station, all historical data record files are transmitted through WLAN, meeting data backtracking and archiving needs.

Enterprise Group – Excellence Award

“Intelligent Rail Transit Express Inspection Vehicles”

- **Shanghai Zan Rail Transit Technology**

The Intelligent Express Inspection Vehicle Packed for Transport (left) and in Operation (right)

Insight – Expert Commentary

> “This work is aimed at the rapid inspection problem of urban rail transit with small and medium traffic. Based on traditional inspection vehicle technology, it has improved the convenience, speed, universality and lightweight performance of the vehicle. A certain degree of innovation and practicability, with certain market application prospects.”
>
> “This work proposes a concept of smart transportation for the existing fast inspection vehicles. It has a good vision for speeding up the maintenance and inspection of urban rail; for inspection digital processing and vehicle automation, it should be studied for progress.”

Inspiration – Basic Idea & Purpose

Intelligent Detection Vehicles (IDVs) are an industry-leading and original product in the field of rail transit maintenance and support. The main function of IDVs is as a platform for rapid transportation of personnel and materials, helping rail transit maintenance and support staff in the process of daily work or emergency repair.

The product can also be used as a platform for intelligent detection equipment. By installing detection modules with different functions on an IDV, rail transit line inspection work can be completed quickly, accurately and efficiently. Detection data can be uploaded to the cloud server, with results analyzed and displayed in real time to quickly and efficiently provide operators with maintenance status and warning alerts. The IDV can therefore provide assistance for the safe operation of rail transit and the construction of "Smart Rail Transit in Smart City".

Innovations – Key Technical Points

The product is made of high-strength, high-precision aluminum alloy, giving it a light structure and good rigidity. It is convenient for manning and transportation, and is also more suitable as a mounting platform for various detection equipment or modules.

The total weight of this product is only 70kg in the basic configuration state, and it is equipped with a detachable lateral push device, so the product can be easily moved in off rail without disassembly. It can safely, freely and quickly turn around on any elevated track section, tunnel track section and ground track section without interference with track peripheral equipment.

This product can realize multi-vehicle marshalling operations. In this state, any car can control the operation of the whole marshalling, and all vehicles in the group can synchronously output driving force or braking force according to the control commands issued by the master vehicle. This can effectively solve the one-time overall transportation needs of large quantities of materials and personnel, thereby effectively improving operation efficiency.

The product needs to be controlled by a dedicated wire controller when the product is running on the track, and can be equipped with maintenance equipment, tools, or spare parts, or can carry up to 4 personnel. It can significantly improve the efficiency of equipment and personnel to the work site. The center of gravity of the vehicle is low even in the state of carrying people and goods, so the risk of vehicle overturning is low.

The product is designed with a unique active driving safety management system based on speed limit and load limit to ensure the safety of the vehicle. In special emergency situations, the product can give full play to its characteristics of fast transportation of people and goods, and can be used as auxiliary equipment to participate in emergency repair operations, thereby significantly improving the efficiency of emergency repairs and reducing the impact of failures.

The side of the product is equipped with a number of special electromechanical integrated quick connection standard ports, which can be used to connect various detection function equipment, so as to realize the multi-functional expansion of the car on the same structural platform.

The product is designed with a unique "steel-aluminum-nylon" composite track wheel, which does not cause abnormal "red bands" of track signals. There is no interference to the track axle counter, no other interference to the line signal system and equipment, no abnormal wear on the rails and switches, and no vehicle intrusion.

The product is designed with a wireless transmission system for vehicle status information. Through the on-board 4G communication network module, the vehicle speed, load, power, operating status of vehicle control system, and various explicit and implicit fault information collected by various sensors installed on the vehicle are transmitted to the designated server in real-time. This function can effectively help equipment managers to understand the vehicle status remotely, and arrange necessary maintenance for the malfunctioning vehicle in time, so as to eliminate related safety hazards in a timely and efficient manner.

Enterprise Group – Excellence Award

“5G Digital Cockpit”

- **Zhengzhou Senpeng Electronic Technology (SENPTEC)**

The 5G Digital Cockpit Installed and in Operation

Insight – Expert Commentary

> “This work uses 5G technologies to implement an "integrated" design of the cockpit control panel, using integrated network architecture to resolve fragmentation of the cockpit control panel and information systems. It is highly practicable and has solid application prospects.”
>
> “This work proposes to use new technology to improve the operation panels of buses, and is certainly innovative; it is hoped that it can be combined with fully automated unmanned driving technology to deepen its application prospects in the future.”

Inspiration – Basic Idea & Purpose

This work meets sustainable development requirements of vehicle electrification, intelligence, and connectivity, while also enhancing vehicle safety. It has upgraded the traditional cockpit layout with an integrated standard platform that is highly adaptable, meeting demand for connectivity and a better driving experience.

Focusing on "information transmission, display, control, and identification", it features 5G communication, navigation systems, onboard vehicle Ethernet, multiple display technologies and array of command and control functionality to improve user experience. Both the physical and psychological stress of drivers is reduced with a more concise cockpit layout and physical switches eliminated, as well as personalized identification verification settings.

It also features integrated network architecture for monitoring, diagnosis and to ensure the smooth communication of vehicles, with enhanced vehicle intelligence making remote control possible.

Innovations – Key Technical Points

The 5G digital cockpit is an integrated, standardized, cost optimized smart digital cockpit solution, which features cockpit domain information fusion technology to achieve a top-level design with networking and power distribution architecture.

It offers an ergonomic solution for drivers, featuring integrated vehicle network architecture and a central control panel, and the cockpit is equipped with a camera-monitor system to replace traditional rearview mirrors, a floating full LCD instrument cluster, a central control panel, a dispatching panel, and a programmable digital switch panel. The switch panel uses high reliability and long-life physical switches to meet the high frequency operations challenge, and all the most important controls and switches are within easy reach.

High-speed 5G communication realizes real-time vehicle status monitoring and cloud management, while the navigation positioning system realizes high-precision vehicle position dynamic information management.

The oxygen anion generator provides 'forest-like' air quality, leading to unconscious reduction of physical and psychological stress, while the air cleaning system provides a clean and safe driving environment to protect the drivers' health.

It possesses a real-time operating system and AEC qualified electronic components capable of full system cold start within 2 seconds, and smart power distribution ensures the safety of the whole vehicle low voltage power distribution system, with fuse and relay eliminated.

Today, cyber-security & data protection is become a big challenge in connected cars in the Internet of Vehicles, and so the digital cockpit communicates through different transmission units of the integrated network architecture, promoting a multi-layered approach to cyber-security by focusing on a vehicle's entry points, both wireless and wired, which could be potentially vulnerable to a cyber-attack. Driver's identification and authentication through a comprehensive ID verification system enhances the vehicle operation safety, with facial, fingerprint and voice options included.

With the development of the Internet, 5G technologies and Cloud Computing, Internet of Vehicles functions will become ever more abundant, with the interconnection of cars and mobile phones still a major trend currently playing out. Downloaded apps on mobile phones or operated from the cloud without the need for apps will realize an ever greater interconnection between cars and mobile phones. At present, the vehicle display still has more importance, but in vehicles of the future the connection will gradually realize technological integration.

University Group – 1st Prize

"Sustainable Concrete Materials from Solid Waste for Transportation Engineering"

- **National University of Singapore**

Recycled Glass Waste Composite Concrete Blocks and Bars Used in this Research

Insight – Expert Commentary

"This work uses recycled waste to develop sustainable concrete, researching concrete using waste glass powder instead of cement, and explored mixing silica fume and slaked lime for early strength and durability tests, with research results having the potential to be applied in the construction of green transportation projects. The works have high scientific research value and practicality."

"Concrete is the most widely used building material in the world, and cement is at the core of concrete. However, cement production consumes a large amount of limestone, coal and electricity, and emits a lot of harmful substances. Therefore, reducing the amount of cement in concrete is of great significance to energy saving, emission reduction and protection of the environment. This work studies the use of recycled waste glass to develop sustainable concrete materials. It tests its reliability, durability and other properties of concrete material mixed with glass powder to explore the feasibility of using glass powder instead of concrete."

Inspiration – Basic Idea & Purpose

In the construction industry worldwide, some 33 billion tons of concrete and 4.1 billion metric tons of cement are being produced yearly. If we can incorporate waste glass into concrete, at a higher percentage of cement replacement by mass, we would be able to "hide" millions of tons of glass waste into our buildings. This would contribute massively to the reduction of landfill usage as well as reduce the usage of cement, which is a heavy contributor of carbon dioxide to the environment. For every ton of Portland cement produced, one ton of carbon dioxide is released into the atmosphere, with the cement industry responsible for about 7% of global carbon dioxide emissions.

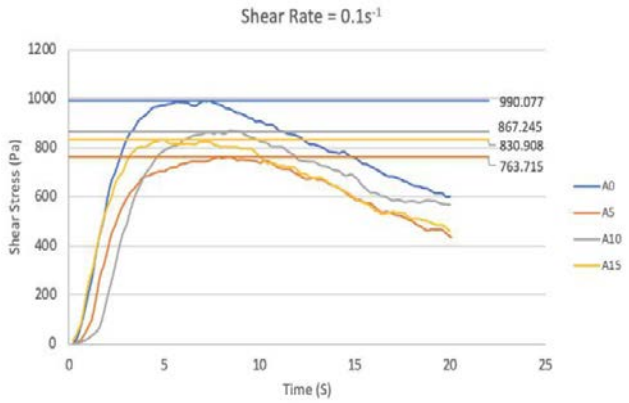
Glass is an element that currently is undergoing low recycling rates in the industry, with about 75% of glass produced ending up in landfills. The overall rate of glass recycling is very low in Singapore at only 14% in 2019, down from 19% in 2018.

The main hindrance to glass recycling is in sorting, since different glass colors and types cannot be mixed and so the sorting process is energy and time consuming, which leads to such low recycling rates. So, if different colored glass could be mixed and used in a mass scale context such as in concrete, the sorting process is not needed and recycling locally becomes easier.

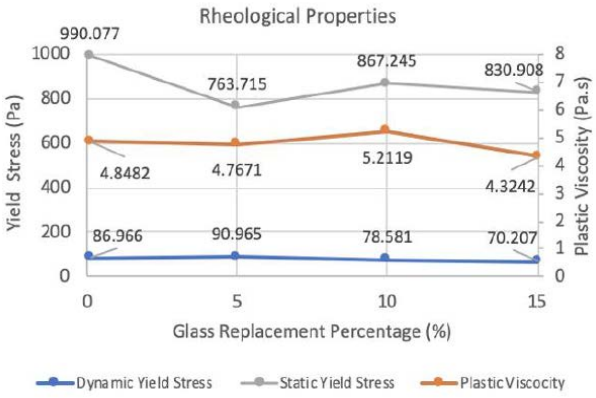
In this work, mixed color waste glass is crushed into fine powders below 45 micrometers, which research shows has pozzolanic properties, and then tested for its mechanical properties and durability aspects of concrete from such composition. The goal is to conduct reliable and repeatable experiments so as to have glass powder recognized as a pozzolanic material that can be used in construction at an industrial scale.

If the strength of the waste glass cement composite is insufficient for use as a core structural material, this work aims to offer sufficient evidence in the durability aspect to allow such composites to be used in non-heavy structural applications such as roadside curbs, fireproofing materials for steel, slabs for pedestrian walkways, and many other potential uses in public transportation infrastructure.

Innovations – Key Technical Points



Sheer Stress for 5% (A5), 10% (A10) and 15% (A15) Mixed Glass Concrete Compared to Concrete (A0)



Rheological Properties of 5%, 10% and 15% Mixed Glass Concrete Compared to

This work aims to develop sustainable concrete from recycled solid waste for transportation engineering. Various properties of concrete with cement replacement of up to 25% waste glass powder were investigated. Previous research shows that glass powder's pozzolanic reaction is slower and hence takes up to or even longer than 28 days for glass powder concrete's strength to catch up with ordinary concrete.

Therefore, the use of silica fume by 5% mass replacement of cement and hydrated lime by 5% addition of cement were also tested. The effect of glass when used in powder form is also documented as having to be checked for cracking due to concrete expansion.

Key advantages of this work can be summarized as follows:

- Using glass replacement mortar in 3D cementitious printing is feasible in a wide variety of use cases, and is more sustainable and more affordable than normal concrete.

- Reducing cement usage through incorporating glass powders into concrete and 3D printing helps the environment as cement production is heavy in carbon dioxide pollution.
- Incorporating waste glass powders as cement replacement helps with recycling and reduces the load of waste glass on landfills.

Since early age strength is required for on-site concrete casting so that works can proceed, this is one of the most important factors to consider for mass use of glass powder incorporated concrete. In terms of durability, alkali-silica reaction expansion tests were also conducted with mortar bars.

Early age strength of 2 days was improved on in this study to suit the site work environment. It was found that adding of both silica fume and lime into the concrete mix aids in improving early age strength of concrete where a portion of cement was replaced by fine glass powders.

It improves both early age (2-7 days) strength as well as the late age (28-91 days) strength and also the elastic modulus of the concrete. Adding silica fume or hydrated lime alone into the mix does not improve the early age strength. In both cases of silica fume or lime, the early age strength of concrete was instead reduced.

However in the later age, the batch with silica fume gained more strength as compared to the batch without whereas the batch with lime remained with a lower strength throughout. Thus to improve only overall strength, silica fume is a good addition as a pozzolanic material. If early age strength is also needed, both silica fume and lime can be added into the mix.

In addition to testing of the mechanical properties, the work explored the viability of the sample with glass replacement to be used for 3D cementitious printing. This was achieved by testing for the rheological properties of the mix, checking the flowability of the mix with slump flow test and simulating the extrusion of the mix with a syringe to quantify the force required to extrude the mix.

Control batches were cast to compare the strength progression of concrete with glass powder versus concrete without glass powder. Quartz powder (inert powder) was also used in one of the control batch as 25% cement replacement by mass to ascertain whether adding glass powders would have any negative effects on the mix.

For 3D printing, the physical properties of mortar were the main focus as these determine how usable glass is as cement powder replacement in 3D printing. Extrudability, pumpability, buildability and flowability were all tested.

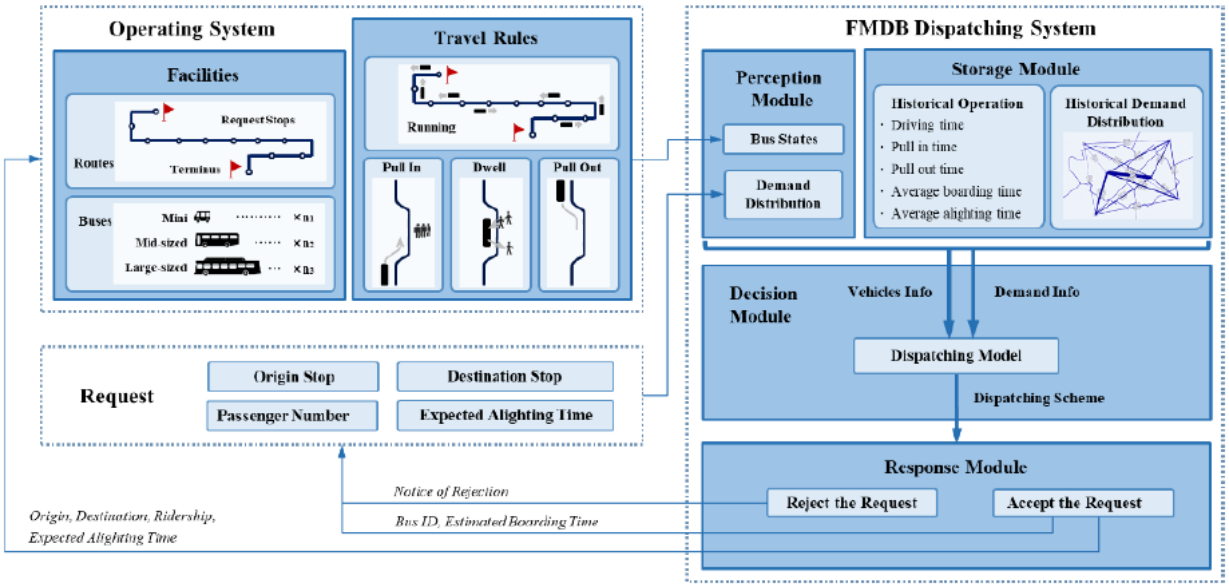
In conclusion, for waste glass replacement, it is best to use it as precast components where early age is not an issue. This is as the unprocessed glass can be then used as late age strength is similar to the processed glass. As durability is still good, the precast non-structural components industry is a good industry to start with glass powder replacement.

As for 3D printing, further testing is needed to ascertain the reason for the varying effects on printability. Recycled glass replacement does seem to improve pumpability but results show that adding recycled glass can increase flowability, reduce buildability and inhibit extrudability.

University Group – 2nd Prize

"Breaking the Impasse on Bus System Benefits: Evaluation and Dispatching Methods"

- **MAGIC LAB**
- **College of Transportation Engineering, Tongji University**



Insight – Expert Commentary

"This work starts from the common challenges of current bus operations: overloads of some sections at peak times, with a large number of empty buses at less busy times. It pursues flexible demand response and scheduling, improving the alignment between supply and demand. By reducing unemployed resources on the road while simultaneously developing a simulation platform for bus dispatching, its index system methodology is very innovative."

"This work proposes a new intelligent bus dispatching method and intelligent dispatching system that comprehensively assesses the two dimensions of time (scheduling) and space (capacity). It puts forward two core indicators, supply and demand for a bus transit service, matching resources through an occupancy index and developing a dual-objective evaluation system."

Inspiration – Basic Idea & Purpose

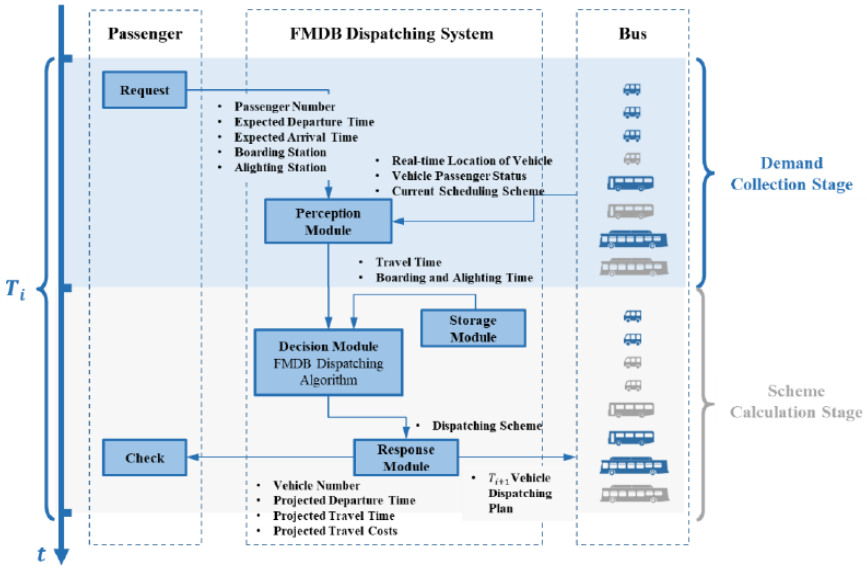
People's travel demand is mushrooming, causing serious traffic jams and air pollution. The priority of using public transport to address this has become a global consensus solution to reduce the use of private vehicles and to promote healthy and sustainable urban development. However, with conventional single-type and fixed-route buses that follow a fixed departure interval, the relatively fixed supply cannot meet time-varying travel demands. Bus overload and empty driving are both common. Nowadays, in the era of Big Data and the Internet of Things, many refined management methods and innovative service modes are springing up. Accurate, easily usable evaluation systems for supply-demand matching and space-time

resource utilization, as well as intelligent dispatching methods, may be an important breakthrough to improve the efficiency of the public transit system.

This work puts forward two core indicators of Supply-Demand Matching and Space-Time Occupancy to describe the degree of alignment between transit service demand and transportation capacity, and the level of occupied road resources. The proposed dual-objective evaluation system can effectively assess underutilized transportation capacity and road resources caused by inefficient dispatching schemes.

Furthermore, a new intelligent bus dispatching method and system are developed that can adjust the supply dynamically according to the fluctuating demand. Flexible departure intervals, different bus types and stop-skipping strategies are adopted. Thus, the limited road space-time resources can be used more effectively to serve actual demands. The efficiency, level of service and sustainability of the public transit system are expected to be truly improved.

Innovations – Key Technical Points



System Dispatching Process

This work derives the Pareto correlation between the two indicators through theoretical and numerical analysis. On this basis, a dual-objective public transport benefit evaluation system is constructed. After theoretical analysis and numerical calculation, the Pareto optimal curve is drawn, with the optimal solution being the upper half of the curve.

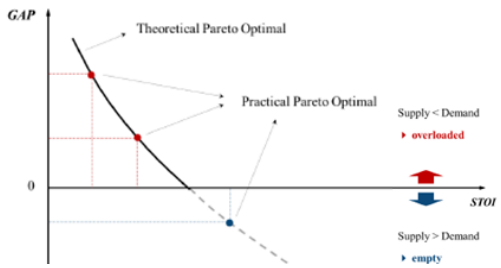
In terms of dispatching algorithms, this research incorporates the optimization of departure interval, combined models, and vehicle-passenger matching into a unified framework for collaborative optimization. At the same time, combined strategies such as station jumping, parking, and speed adjustment are introduced, and the MILP model is proposed and improved through Lagrangian relaxation and genetic algorithms that are applied to model solving to improve efficiency in large-scale scenarios.

□□New Index

Different from the current research, the supply-demand matching index proposed in this work innovatively evaluates the transportation capacity of the public transportation system as a balance between supply and demand, and directly quantifies the fundamental difference. The Space-Time Occupancy Index (STOI) extends the traditional ‘time’ dimension (scheduling) evaluation to the ‘space’ dimension (capacity) innovatively, which can accurately quantify wasted time and space resources and effectively connect this in to the public transport network. At the same time, the theoretical analysis and derivation of the index formula shows that the

new indexing proposed in this work satisfies the additivity of the index under different spatial and temporal granularity, demonstrating its robustness.

□□New System



Pareto Optimality of Gap and STOI

This work establishes a dual-objective Pareto evaluation system based on the internal relationship between the two indicators. It explores the relationship between *Gap* and *STOI*, concluding that the optimal solution of the two should fall on the Pareto curve and determining its solution set based on the actual situation according to Pareto theory. The analysis found that the two indicators have a deep relationship with the commonly used indicator for public transportation efficiency evaluation –total travel time. *Gap* and waiting time are positively correlated, as are *STOI* and travel time. The dual-objective evaluation system can directly reflect supply-demand matching and space-time occupancy, which indirectly reflects the total travel time. It is an effective refinement of the traditional evaluation system.

□□New Method

The intelligent dispatching algorithm proposed in this work starts with passenger demand allocation and vehicle dispatching, and then integrates the demand-responsive shared travel system with the public transportation system. This new dispatching algorithm simultaneously combines variable departure intervals and flexible vehicle combinations, introduces flexible strategies such as stop-hopping and speed adjustment, which can effectively improve the balance between supply and demand. The system retains the characteristics of basic operating routes and transportation corridors, is more suitable for large-scale passenger flow demand, and can effectively reduce the occupation of road time and space resources.

This work has strong practicality and high application value. The evaluation method has high operability and portability. The new flexible and intelligent dispatching technology of can adjust the dispatching plan in a demand-responsive manner, so that the transportation energy supply can effectively meet actual passenger flow demand, tap the service capabilities of the existing network infrastructure, and avoid waste of transport resources. It is now possible to dynamically change the schedule of bus departures and stops according to actual needs with the provision of sufficient technical support for the application of demand-responsive intelligent dispatching algorithms.

The intelligent bus dispatching method optimizes the dispatching strategy on the existing bus infrastructure, improves the operational efficiency of the bus system, and effectively reduces the number of roads. Wasted resources and transport capacity are applicable to different passenger flow scales and demand distributions, and can therefore be extended to the public transportation systems of various economies and cities of different sizes.

University Group – 2nd Prize

"Does Asphalt Hot-Mix Recycling Provide Enough Friction?"

- **Naresuan University, Chiang Mai University**
- **Infraplus Co.,Ltd.**

Insight – Expert Commentary

"This research analyzes the safety level of asphalt hot-mix recycled pavement, discusses the influence of the gradation and proportion of recycled materials on the thermal friction performance of asphalt pavement, and provides a new reference direction for road management departments."

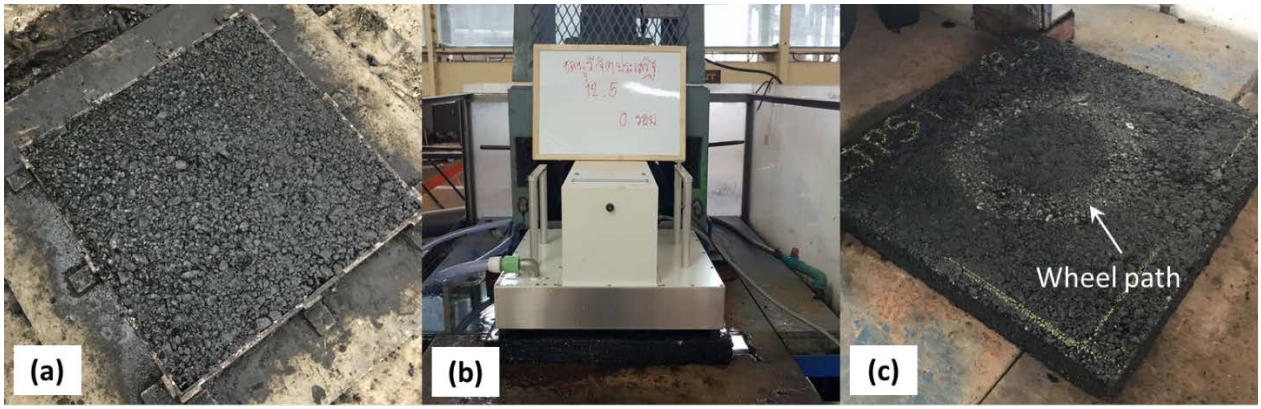
Inspiration – Basic Idea & Purpose

Recently, Recycled Asphalt Pavement (RAP) is increasingly employed as the main source for hot-mix asphalt manufacture. Past research has focused on evaluating the performance, workability, and constructability of asphalt hot-mix recycling. However, there has been limited research with regards the effects of RAP on road safety.

The safety of road and public transport users depend greatly on the frictional characteristics of the road surface, with slippery road surfaces inevitably leading to a higher incidence of serious and fatal road accidents. The key frictional characteristic of road surfaces is 'skid resistance', which is conventionally used to determine the current level of safety of a road surface. The skid resistance of asphalt materials used in road surfaces depends largely on their binder properties and aggregate properties, as well as the construction methods employed, traffic conditions and climate conditions. Moreover, the skid resistance of road surfaces is degraded or reduced over its structural lifetime depending on its durability, making older surfaces increasingly hazardous over time.

This work examines the safety level and durability of road paved by asphalt hot-mix recycling. The effects of gradation and proportion of recycled aggregate on skid resistance are investigated, and surface deterioration is assessed based on laboratory simulation.

Innovations – Key Technical Points



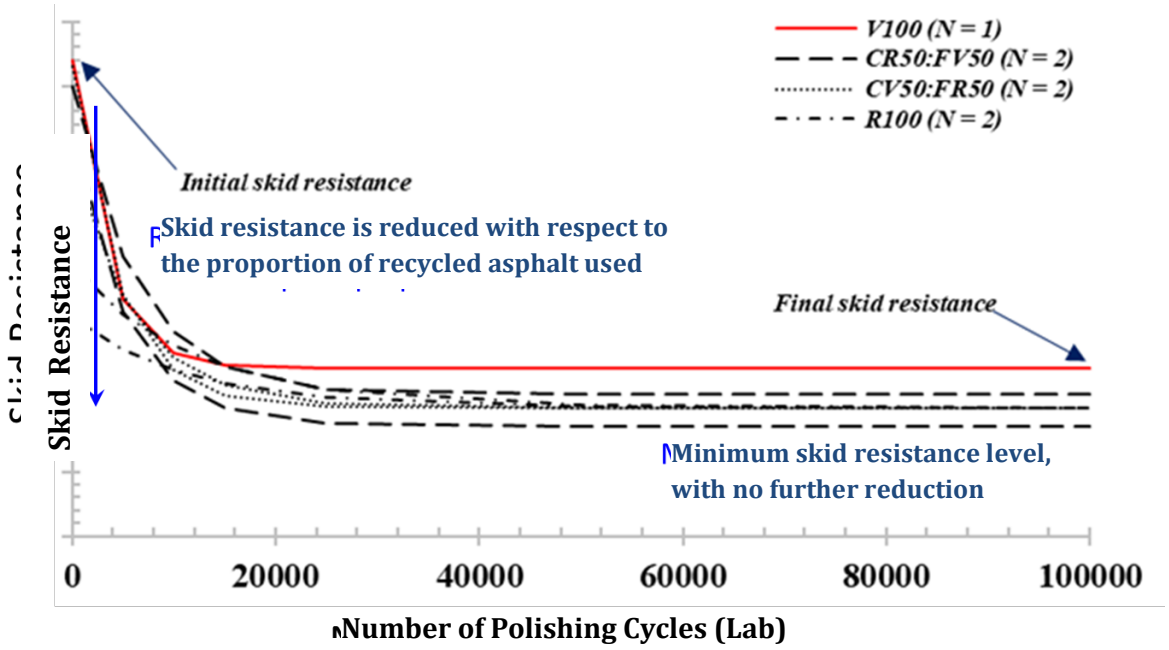
Asphalt Specimen (a) before Polishing, (b) during Skid Resistance Testing, and (c) after 50,000 Polishing Cycles

The deterioration of asphalt hot-mix recycling due to traffic is simulated by an accelerated polishing machine. As a result, the skid resistance of asphalt hot-mix recycling is compared with conventional hot-mix asphalt concrete, with the effects of RAP proportions and gradations also examined.

Standard aggregates, new asphalt binder, and RAP are the main ingredients for asphalt hot-mix recycling. Four different types of mixture were designed to investigate the effects of RAP contents to skid resistance of asphalt contents. The durability simulations of these mixtures were manufactured by an in-house developed Three-Wheel Polishing Device (TWPD), which simulated the deterioration of asphalt surface through traffic abrasion very well, with skid resistances reduced with the increase in number of polishing cycles.

After the hot-mix recycling specimens were polished to designated levels, the skid resistances of the sample surfaces were measured by a British Pendulum Tester (BPT) and Dynamic Friction Tester (DFT). The skid resistances measured from the different mixtures were then compared and analyzed, with maximum skid resistance observed at the initial stage and minimum skid resistance attained after some period of road usage.

Test results obtained from this study are shown in the following graph, with two specimens prepared for each different mixture. The mixture with 100% of fresh aggregates and virgin binder is illustrated by V100 in red, and the mixture with 100% recycled asphalt pavement is represented by R100. The other two mixtures are the blends between recycled pavement and fresh aggregates, with CR50:FV50 indicating the use of 50% coarse recycled aggregates, and the CV50:FR50 containing 50% coarse fresh aggregates.



Experiment Results Showing Skid Resistance Performance by Simulated Deterioration of Different Mixtures

1. The skid resistances of all mixtures tested were reduced to their minimum values by around 20,000 cycles of polishing. The minimum values were then maintained at constant values until the limit of the experiment at 100,000 cycles of polishing.
2. The proportion of aged binder in the mixture strongly influences the initial skid resistance. The difference in performance between the V100 and R100 mixtures shows that increased proportions of aged binder significantly reduces initial skid resistances. The hard and stiff responses of aged binder might be the cause of slippery surfaces, with lower skid resistances of the recycled asphalt mixtures at the initial stage.
3. The minimum skid resistance of all mixtures is nearly the same, and although the minimum skid resistance of the V100 mixture was higher than that observed from the mixtures with recycled asphalt pavement, the difference was minimal and within acceptable limits.

Test results obtained from this research illustrate that the proportion of recycled mixture affects the skid resistances at the initial stage of road surfacing far more severely than at later stages, once the minimum skid resistance value is reached. The lower skid resistance of recycled asphalt pavement may be caused by the stiffness of aged binder contained in it.

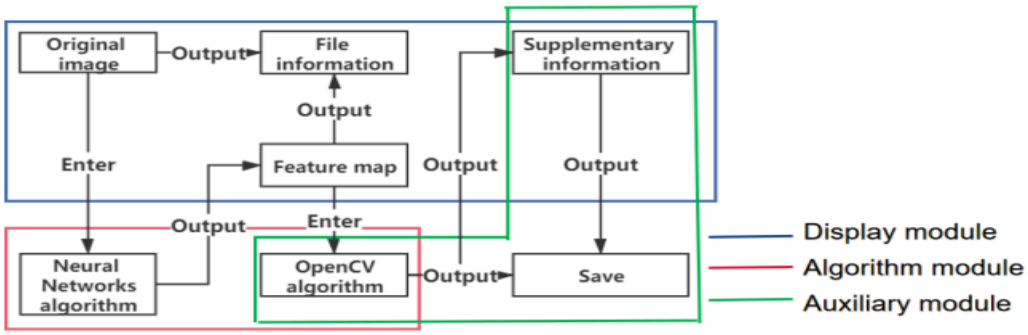
This research promotes the use of recycled pavement materials for sustainable and eco-friendly development, showing that given the right gradations and mixture of aggregates, recycled hot-mix asphalt does provide enough friction. Beside the performance of asphalt hot-mix recycling, the safety aspects of materials are characterized in this research. The skid resistance reduction of pavement surfaces with respect to time and traffic, therefore, can be characterized based on the testing framework developed in this research.

The findings analyzed from the test results can be used as the guideline development for hot-mix recycling mix design. The effects of RAP contents and other parameters are interpreted and summarized, and road authorities will be able to use these results for their future reference.

University Group – 3rd Prize

"Rail Surface Defect Recognition Model Based on Deep Learning"

- **Shanghai University of Engineering Science**



Development Flow Diagram

Insight – Expert Commentary

> "Aiming at the problems in the detection of rail surface defects, this work integrates three aspects of rail, deep learning and machine vision. According to the characteristics of rail surface defects, a saliency detection of the residual neural network of the opportunistic codec is designed. The work has a complete structure, clear expression and strong logic."
>
> "The work makes use of cutting edge deep learning methodology and computer neural networks to improve rail surface defect detection accuracy and enhance robustness. It has high research value and practicability for the intelligent maintenance of tracks, and has very good market prospects."

Inspiration – Basic Idea & Purpose

This work is designed and developed to solve the problems existing in rail surface defect detection, such as original detection method, consuming manpower and material resources. It combines rail transit, deep learning and computer vision to develop a rail surface defect recognition model.

In the past, the algorithms used in artificial intelligence detection programs with visual interactive interfaces were relatively backward, and the detection accuracy and robustness were poor. The users of more advanced significance detection neural networks are mainly professional calculator visual researchers, and no visual interactive interface has been developed.

The detection application based on deep learning has complex steps in practical use, and many paths and parameters need to be constantly adjusted before the optimal model being trained. Therefore, in view of the problems above, the focus of this work is to:

(1) Design and develop a functional deep learning rail surface defect detection software that provides convenience for users, and whereby the algorithm can truly realize the end-to-end application of technology;

(2) According to the characteristics of rail surface defects, a significant detection neural network is designed to make rail surface defect detection more accurate and robust.

This work is a rail surface defect recognition model based on deep learning, comprising an object location algorithm, a neural network image saliency algorithm for rail surface defect detection, and a rail surface defect recognition software terminal system.

Innovations – Key Technical Points

Based on the established development process, the final software model has the following innovations:

(1) Based on deep learning and according to the characteristics of rail surface defects, this work designs and builds a neural network using PyTorch for detecting rail surface defects;

(2) This work uses the rail surface defect detection software based on deep learning developed by the Python Tkinter. The display and operation interface style are friendly, the developed rail surface defect detection software is rich in function and variety, and the feature map is processed in a different form.

The main technical features of this network are:

(1) Using a novel end-to-end residual network to detect defective objects, the network alternately uses the channel weighting block and the residual decoder block to gradually recover the predicted spatial saliency value from the encoded multi-layer semantic features, which realizes the complete detection of the defect object and the effective suppression of the non-significant background;

(2) An optimized network is designed, i.e. a Residual Refinement Structure with One-Dimensional filters (RRS_1D). The algorithm can further optimize rough predictive significance mapping and output high quality detection results with accurate boundaries and a compact defect object area saliency. In addition, using one-dimensional filters is computationally efficient and can be used to improve the performance of existing depth models due to its highly modular structure. The experimental test of rail surface defect data sets proved that the model used in this work is superior to other advanced detection methods, and has strong robustness and better detection efficiency.

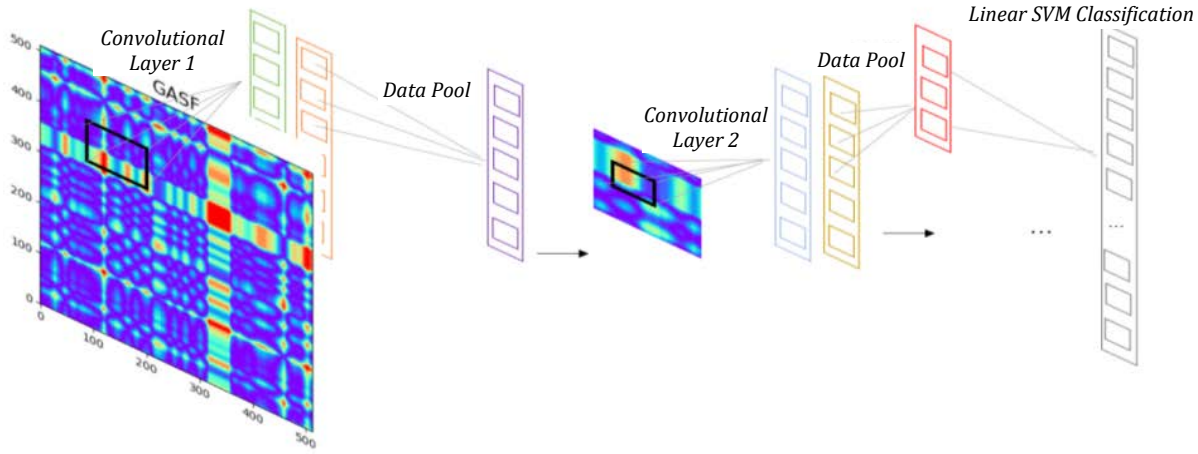
This work uses a large number of rail surface defect data sets to carry out a large number of experiments on the saliency detection neural network based on codec residual neural network. The experimental results of other traditional methods and the same kind of neural network detection methods are compared.

The model shows great scientific significance for the study of rail surface defects, and also shows great practical and economic value for the development of intelligent detection and maintenance of rail transit.

University Group – 3rd Prize

"Rail Fastener State Detection Method Based on Vision and Vibration"

- **Shanghai University of Engineering Science**



Convolutional Neural Network (CNN) Structure

Insight – Expert Commentary

> "Track fastener detection is a major issue related to the safety of rail transit operations. The work proposes a detection method based on the fusion of vision and vibration to improve the accuracy of detection, which is worthy of recognition."
>
> "Rail fasteners are line infrastructure and are very important for driving safety. However, due to the large number, daily inspections involve a lot of labor and workload. This work can effectively improve the accuracy and timeliness of fastener state detection through the detection method of vision and vibration fusion, and effectively improve the quality of dynamic detection of equipment status, which has good application and promotion value."

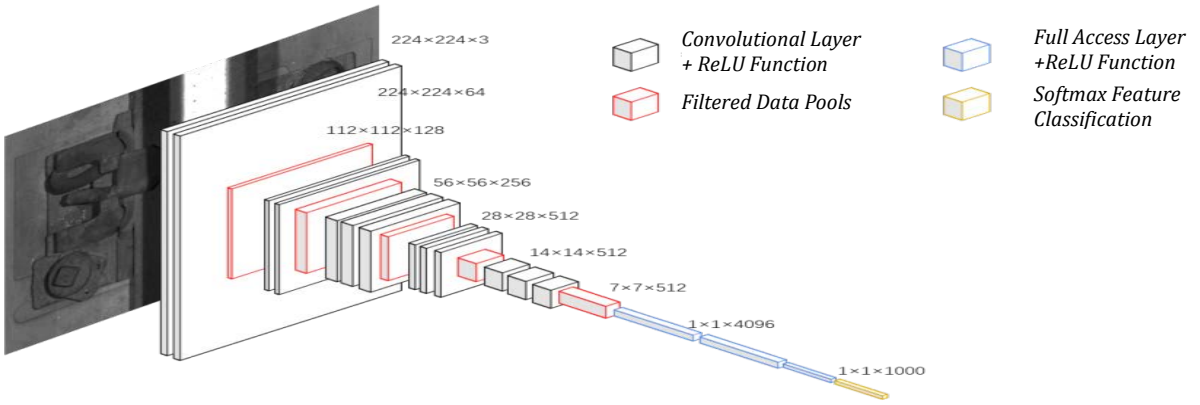
Inspiration – Basic Idea & Purpose

Smart monitoring and detection of railway infrastructure is an inevitable requirement for railway development. Detection technology that integrates visual information and vibration data is a new type of rail transit solution that can effectively ensure the high-quality and safety of rail vehicles. The inspection of fasteners is an important part of this solution. Fasteners connect rails and sleepers to form a rail row. The lack of fasteners may cause major accidents such as train derailment and this poses a great threat to operational safety. Traditional fastener detection has always relied on manual labor and static detection. This method lacks real-time observation and accuracy. This work proposes a fastener detection method based on machine vision and vibration signals to improve the accuracy and efficiency of rail fastener detection.

It does this by using a neural network to extract the unique discernible features of visual signals and vibration signals respectively. This uses a deep learning manifold as a fusion network to

extract combined features in a mixed feature vector, augmenting this with a support vector machine classifier for dynamic diagnosis.

Innovations – Key Technical Points



VGG-16 Network Structure

This work combines visual information and vibration data to detect the status of rail fasteners. The process takes rail fastener images on the spot, segments images in time series based on the structural characteristics of the fasteners, uses a Convolutional Neural Network (CNN) to extract image features, classifies fastener image features into different states, and extracts visual perception feature vectors.

The vibration signal at the fastener is measured by following the time sequence of image capture. The signal is classified according to the status of the fastener vibration. After separating the vibration signal and extracting the feature vectors, the two feature vectors are merged to construct a feature model to detect the status of a track fastener.

Singular image detection is affected by extreme weather such as strong light and rainy weather, which can lead to insufficient detection accuracy. Singular vibration signal detection will cause excessive vibration signal noise due to uneven track and other reasons, and can lead to poor detection. By fusing visual information and vibration data to detect the status of rail fasteners, the detection effect of rail fastener status is improved.

Key technology employed by this work include: Gram Angle Fields, Convolutional Neural Networks, VGG-16 and SVM classifiers.

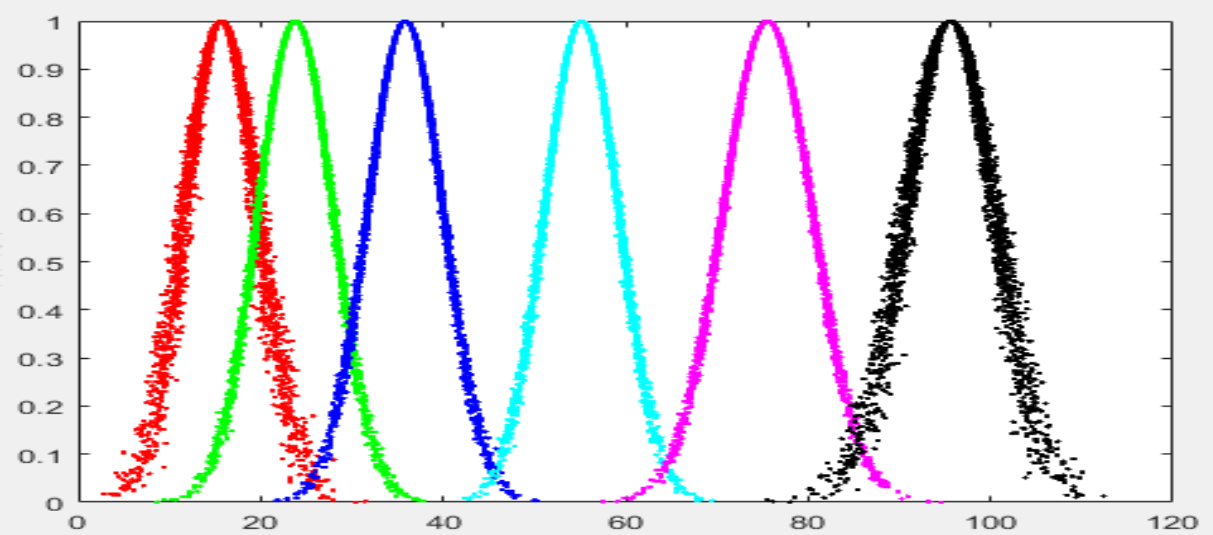
This design proposes to transform the timing signal into an image, and extract the two-dimensional features of the original data without defined parameters through CNN. Combining the features identified by the visual signal, the two are merged to improve the detection accuracy of the rail fastener status.

This method can be used to collect vehicle axle box vibration signals and fastener images, and import the two into the diagnosis model for calculation to effectively obtain the resultant fastener condition.

University Group – 3rd Prize

"Ride Comfort Evaluation of Urban Rail Transit Based on the Cloud Model"

⊙ **Zhejiang Normal University**



Ride Comfort Index Scores of Urban Rail Trains in Cloud Models of each Risk Level

Insight – Expert Commentary

> "The comfort of urban rail transit is a global problem. Through cloud computing technology, the CRITIC method is used to evaluate reliability, noise levels, air quality, capacity and other important indexes, which provide a powerful way to improve design management and service support levels. The work is innovative, advanced and has application prospects."
>
> "The evaluation system proposed in this paper for passenger comfort using the cloud model is novel, and the calculation method is scientific and supports the development of cloud-based urban rail big data."

Inspiration – Basic Idea & Purpose

With the promotion of the concept of green development of urban public transport, urban rail transit has ushered in a golden period of development in China. It plays an increasingly important role in the daily travel process of passengers. As the most important part of passengers' experience in choosing urban rail transit, the ride comfort of urban rail train is worthy of attention. This study deepens the analysis on urban rail ride comfort through the application of the cloud, so as to bring better service to passengers. It also hopes to provide some suggestions for the operators and managers of urban rail transit.

Ride comfort evaluation of passengers in the process of taking urban rail transit is dependent on their subjective views. In view of the difficulty in quantifying qualitative indexes in ride comfort evaluation, an index system was established with 5 measures. Each evaluation index was defined and the weight of each index determined by the 'CRITIC' method, this forming the basis of effective urban rail transit ride comfort evaluation.

Taking passenger ride comfort evaluation of a subway line in Hangzhou as a case study, an empirical study was carried out to verify the effectiveness and rationality of the evaluation method. The research results can provide reference for the improvement of urban rail train ride comfort.

Innovations – Key Technical Points

The CRITIC method is an objective weighting method that takes into account not only the variability of the data within the indicators, but also the correlation of the data and content of the indicators, using the comparative strength and conflict of the indicators to determine the weight of the indicators and better reflect the dynamic views of passengers in transit.

The cloud model has three digital features, namely the expectation of cloud usage, entropy and hyper-entropy. Taking each passenger as a cloud droplet, the overall characteristics of the cloud formed by the comprehensive evaluation results of all indicators by all passengers reflect the evaluation results of passenger ride comfort of urban rail trains.

There are many influencing factors in the evaluation of urban rail train ride comfort, and the influence degree of each factor is different. The selection of indicators is the key link to obtain more accurate evaluation results. The evaluation index of urban rail train ride comfort includes reliability, noise, air quality and train load ratio.

At present, this method is suitable for urban rail transit operators and operation managers to understand passengers' rail transit needs. However, this method can also be applied to the evaluation of the ride comfort of railway passenger cars and bullet trains, as well as the process evaluation research related to railway passenger cars and urban rail trains.

The method is standardized in data processing and considers the influence of index variation on index weight as well as the conflict among indexes, so it is suitable for resolving multi-attribute and multi-decision problems. It can also provide technical reference for operational managers to make relevant decisions.

Based on the concept of "people-oriented" passenger service, a dynamic evaluation method for the ride comfort of urban rail trains is established, and a method for evaluating the ride comfort of urban rail trains is determined according to CRITIC method and cloud model theory.

The application of this method takes into account the dynamics and ductility of the evaluation, and the relative objectivity of the measured data, as well as the discreteness and distribution ranges of the data, so it has general applicability.

It is hoped that this study can provide some reference for the follow-up study on the ride comfort of urban rail trains, and can continuously improve the service quality of urban rail transit in the future urbanization process and the growing mileage of urban rail transit.

University Group – Excellence Award

“Subway Train Onboard Filters”

- **Tongji University**

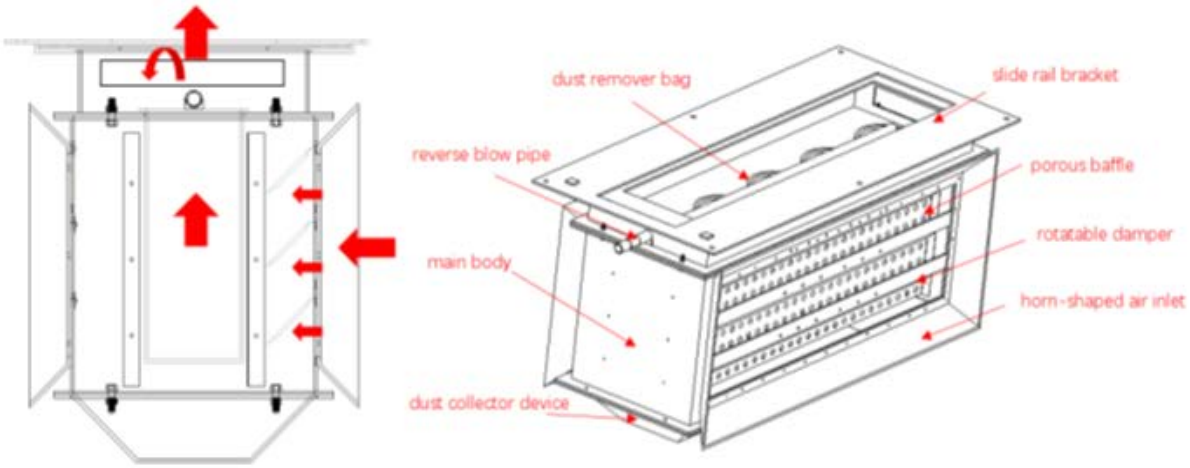


Diagram of Dust Removal Device & Schematic of Air Purification Device

Insight – Expert Commentary

> “The bag filter designed and installation at the bottom of the subway train is highly innovative and practical, and can better remove dust and pollutants in the tunnel. It has very good application prospects. The work has a complete structure and strong logic.”
>
> “The work is innovative. It raises the problem of dust in train transportation and proposes some methods; however, this solution is still debatable in terms of increasing the weight of the train and operation and maintenance.”

Inspiration – Basic Idea & Purpose

This work designs a filter which can be installed at the bottom of subway car. Horn-shaped air inlets and rotatable air inlet doors are symmetrically arranged. The air inlet doors will open under wind pressure. A porous baffle is set behind the air inlet door to slow down the wind speed. Dust removal bags are set behind the porous baffle to intercept the particles. A reverse blow pipe is set on the upper position with nozzles on it, through which the compressed air can blow down the particles accumulated outside the bag. A dismountable dust collecting device is set at the bottom to collect particles.

When the subway train runs, the air doors on the windward side open under wind pressure, and the dusty air in the tunnel enters into the device and hits the baffle. The large particles are separated under the inertial action and fall on the dust collecting device. Then the air collides with the dust removal bags. The purified air flows out from the bag outlet, and then leaves the dust collecting device on the top.

This work makes use of the kinetic energy of the subway train when it runs and no fan or power supply is needed. It can absorb the particles generated by friction during the subway operation, purify the tunnel environment, and protect the health of subway commuters and staff.

Innovations – Key Technical Points

This work can be installed by the slide rail bracket, which has a simple structure and can be fixed on the bottom of the subway. The main body of this work is installed on the bracket by means of a sliding rail and is fastened by clamp to prevent itself from falling due to vibration during the train operation.

The horn-shaped air inlets designed in this work are riveted with the main body of the device, which can expand the air inlet area and increase the wind pressure at the rotatable damper. The rotatable damper designed in this work has a stepped structure, which is adapted to the main structure of the device, and is convenient to install. The dampers are arranged symmetrically on both sides of the main body of the device and each side sets three doors, which can save space.

When the subway train runs in one direction, the air doors on the windward side open under the wind pressure, while the air doors on the leeward side close under the wind pressure and gravity, so that the airflow can pass through the cloth bag and then leave from the air outlet. When the subway runs in another direction, the original leeward side becomes the windward side, and the corresponding side air doors open under the action of wind pressure. The original windward side becomes the leeward side, and the side ventilation doors close. In this way, it can be ensured that no matter which direction the subway is running, the airflow enters the dust removal device through the baffle first, then enters the dust remove bag, and then flows out from the upper air outlet.

A porous baffle is designed in front of the dust remove bag, which can limit the wind speed and act as a primary filter to a certain extent. When a part of the high-speed dusty airflow hits the baffle, the large-size particles will be separated due to inertia and fall into the dust collecting device below. This work also uses polyester needle-punched felt bags, which has the advantages of high porosity, good air permeability, high dust collection efficiency and long service life.

The dust removal device designed in this work can move with the car to clean the particulate matter in the subway tunnel in real time. Compared with traditional industrial dust collectors, this product has the feature of self-adaptation as the air inlet direction can be changed according to the forward direction of the train, in addition to being able to move with the train.

The innovative method used in this work is to treat the particles at the source, when they are generated. It can work during the operation of the subway, without waiting for the subway to stop running.

University Group – Excellence Award

"Smart Multimodal Transportation Mobile Application and Fleet Management System"

- **Iloilo Science & Technology University (ISAT U), Philippines**

The Triptify Fleet Management System Dashboard

Insight – Expert Commentary

> "The work has developed a smart multimodal mobile phone application and fleet management system, the purpose is to ensure a fast, reliable and safe commuting environment for the public. The application of four innovative technologies is practical and has market application prospects."
>
> "Urban public transportation fleet management is the most fundamental and essential management unit. Traditional fleet management and rapid urban development have brought a lot of lag. This work has feasibility from research on fleet management innovation and application development. It has made a practical contribution to fast, reliable and safe commuting in the western Philippines to minimize traffic congestion, traffic accidents and pollution."

Inspiration – Basic Idea & Purpose

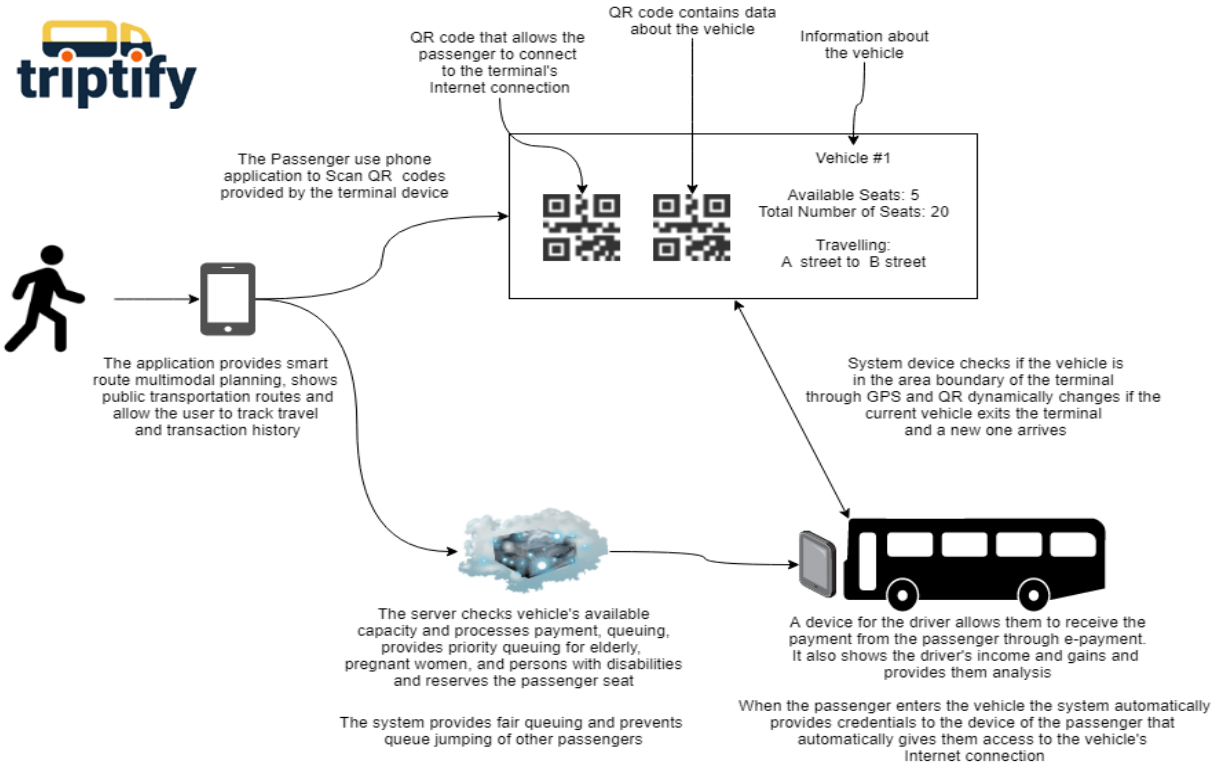
Due to the rapid urbanization, population density and growth of the Philippines, this has led to traffic congestion in roads of major cities throughout the economy. The reduction of private vehicle dependency is a good pathway to achieve sustainable mobility; increasing shares of public modes of transport contribute to improved traffic flow, energy-saving, emission reduction, and social equity.

This work aims to improve the Philippines' current transportation dilemma by using transport models that integrate older modes with newer travel transportation methodologies towards sustainable and modernized mass transit systems.

The project is able to address issues in mobility by allowing the users to plan their preferred routes in advance. Using computing technologies, the system is able to determine available modes of transport to and from the selected destination. Other features such as travel queuing, alternative route determination, and contactless payment are also made available.

This work introduced a portable wifi stand at the terminal to give data connectivity to passengers without mobile data so they can access the full features of the current technology.

Innovations – Key Technical Points



The Triptify Commuter Interface Overview

The result of this study is the development of a Fleet Management System and Application which efficiently optimizes complex transportation-related internal servicing and total operational activities of the mass transit driver associations in the Western Visayas Region of the Philippines, ensuring fast, reliable, and safe commuting as well as reducing congestion, accidents and pollution.

The software development method 'Evolutionary' was used to develop incremental prototypes, each with additional functionality or improvements, until the final product emerged.

The system, branded as 'Triptify', features a fleet management system dashboard that contains Franchise Files for maintenance, compliance and other services; Driver Files for driver profiles, performance evaluation, and navigation and communication tools; Organized Dispatch features vehicle and driver planning, driver dispatch protocols, and task management activities; and other reporting, performance and vehicle service features as shown on the previous page.

The commuter mobile application is designed and implemented as an android application and is able to display public transport routes, estimated arrival times, as well as passenger ratings.

University Group – Excellence Award

“Intelligent Monitoring and Risk Warning System for Shield Construction of Urban Rail Transit”

- **Soochow University**

Color Mapping of the Chang Tu Information Platform

Insight – Expert Commentary

> “The safety of rail shield construction has always been the focus of rail transit construction. The work shows that intelligent risk detection and early warning forecasting is of significance and has broad application prospects.”
>
> “This work develops a rail transit shield construction intelligent risk detection system through the fusion of multi-source data and machine learning technology, so as to display real-time intelligent simulations of the construction process and shield deformation prediction. The results have good engineering application value. It is recommended to increase the collection interface of soil layer digital information and related peripheral detection data to improve accuracy.”

Inspiration – Basic Idea & Purpose

With the rapid development of "new infrastructure", the construction of urban rail transit requires technological innovation as the driving force, information network as the basis, and digital transformation and intelligent upgrading to meet the needs of high-quality development. The construction environment of rail transit is complex and harsh. Once a safety accident occurs, it will cause huge economic losses and serious social impact, even casualties.

It is necessary to carry out real-time monitoring and risk early warning on the construction environment. This work can provide a system software for the owner, the construction party and the supervisor to manage and process the monitoring information in the construction period and the operation period.

With the development of the era of the smart economy, software development and integration for large-scale construction projects construction monitoring and early warning forecasting has great potential. This work is an information construction technology for real-time monitoring, control and dynamic risk alert that provides intelligent technical support for urban rail transit construction.

Innovations – Key Technical Points

This work develops an intelligent monitoring and warning system tailored for the shield construction of urban rail transit, which combines multi-source data, Geographic Information Systems (GIS), Building Information Modeling (BIM) and Machine Learning (ML). The system provides a digital platform to display the process of shield tunneling, and the main functions include data collection, construction monitoring and risk warning by using sensor technology, Internet of Things (IoT) and Big Data (BD) analysis.

The proposed system aims to visualize the urban rail transit shield construction, improve the efficiency of monitoring data processing, provide timely risk warning, and eventually realize intelligent management on the construction site.

Technical innovations include:

1. Real-time and intelligent simulation display of the shield tunneling process and conceptual modeling for dynamic control of shield construction safety

2. Multi-source heterogeneous data processing and multi-source data fusion with a shield process data acquisition service and integrated management system

3. Deformation prediction and early warning in the process of shield tunneling for all participants involved in shield construction

The main function of the configuration software for remote monitoring of shield tunneling is to monitor the changes of shield tunneling parameters. The data collected at each site is sent to the database in the cloud server, and then interpreted by the main program to draw various interfaces.

The shield construction monitoring module is comprised of the shield construction project digital model, the real-time display of data, and dynamic query analysis. The digital model provides a supporting simulation environment for shield tunneling through multi-layer interaction and multi-channel display.

The online monitoring system is divided into the status monitoring and the oil monitoring modules. The monitoring data are collected and stored in real time, then summarized and analyzed to realize alarm and prompt functionality.

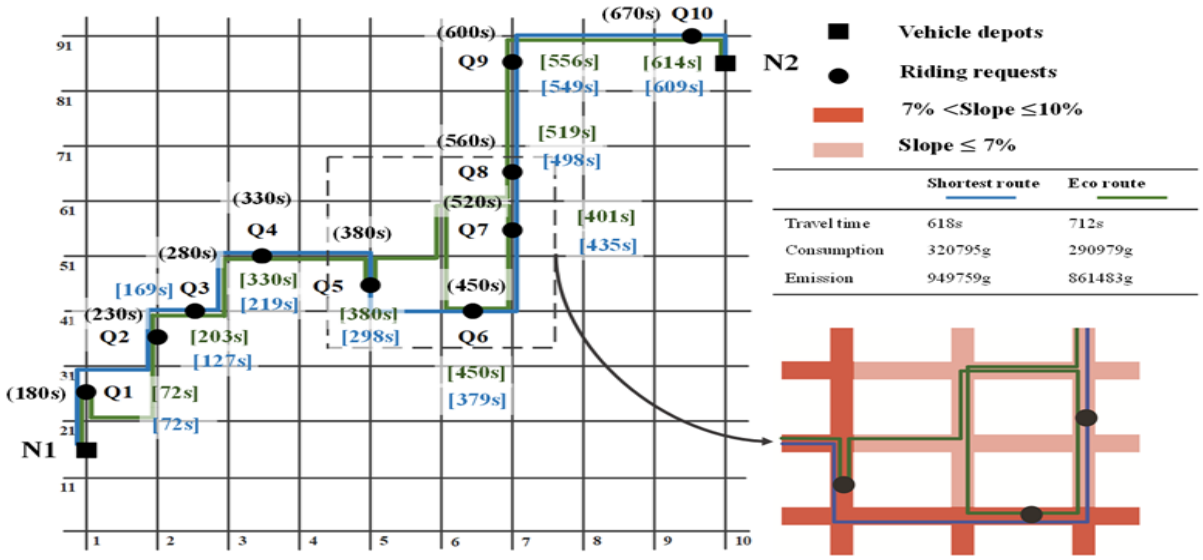
For forecast warning, the deformation prediction model of shield construction is established. The shield construction behavior database is formed, including geometric dimensions of the tunnel, stratum properties and shield construction parameters as target variables, and settlement deformation as target response.

Machine learning algorithms, such as BP Neural Network, LGBM and XGBoost, are used to analyze the nonlinear correlations between input variables and target responses, so as to predict the deformation of shield construction and identify abnormal deformation. The model is then embedded into the visual early warning platform.

University Group – Excellence Award

"Design and Optimization of Demand Responsive Transit System Considering ECO-Routing Strategy"

⊙ Dalian Maritime University



The Proposed ECO-Oriented DRT Service

Insight – Expert Commentary

"The concept of eco-friendly transport aligns with high quality of life and quality, sustainable development. It is the responsibility of us all to work towards "carbon neutrality". This work focuses on passenger needs and demand-responsive buses, using novel technical means that realize ecological efficiency in public transportation, emissions reduction, and environmental protection."

"This work aims to reduce fuel consumption and emission demand response. Through comparative analysis and related indicators of traditional methods, the advantages of this method and its optimization effect in eco-driving can be visually demonstrated. The research can be applied more broadly to the taxi industry, but public buses are increasingly purely electric."

Inspiration – Basic Idea & Purpose

The transportation industry is experiencing a crisis of oil shortage and serious greenhouse gas emission. Road transportation is the largest sector of oil consumption, also producing roughly one quarter of total carbon emissions worldwide, a major source of environmental pollution.

In recent years, with the rapid development of Connected Vehicle (CV) technology, public transport services can significantly profit from new CV data, such as traffic state, geometric design, terrain information, and signal timing, laying a solid foundation for more advanced ECO-Routing systems.

ECO-Routing is inspired by the potential to be an effective way to improve fuel economy and save the environment in the near term. This work aims to optimize environmental routes with

the least consumption of gasoline and proposes useful guidance, such as driver behavior training, intersection management and vehicle trajectory optimization.

Demand Responsive Transit (DRT) is designed to offer flexible transit services, in which buses are dispatched with dynamically modified routes and schedules to varying demand in boarding time windows and destinations. This work takes a DRT services mechanism and embeds it with an ECO-Routing system that offers optimized environment-friendly route planning.

Innovations – Key Technical Points

In order to further develop ECO-Routing techniques for serving mass transit systems, the work contributes to: developing a DRT-oriented eco-routing framework in which vehicle dynamics and emissions are integrated into the DRT operational framework; minimizing of fuel consumption and emissions in response to complicated traffic conditions and different types of road geometric design in DRT routing and scheduling plans; proposing an efficient solution algorithm for reducing the computational burden in preparation for future on-road applications.

Integrating the ECO-Routing strategy within DRT system design, traditional methods aiming at the shortest routes are improved upon. Fuel consumption and emissions are considered as optimization objectives aligned with building a greener transit system. It focuses on route and schedule design with discrete and heterogeneous demand in the real world and realizes the joint optimization of velocity profile and route selection from the macro system design to micro vehicle scheduling, to improve operational efficiency and service reliability based on driving guidance.

Road network information, including traffic status and road features (i.e. slope), is integrated into the optimization process, dynamically updating vehicle mass in accordance with passenger load profile to estimate the impact of passenger distribution on fuel consumption and route selection.

This research is suitable for the construction of green and intelligent DRT system in different cities. With the rise of Connected Autonomous Vehicles (CAV), it will present higher practical application value and broader development prospects. Besides the DRT system, this research can provide inspiring and technical supports for other eco-oriented transit systems.

Overall, the flexibility and adaptability of DRT services allow the application of eco-routing where the generated benefits might be even more clearly seen as the detour is often observed in more established DRT service design.

Conclusion

Bottle of Champagne Raised in Celebration at the Successful Conclusion of the INPUT Competition Awards

We would like to sincerely thank the various economies and everyone involved in the competition, especially each and every member of the judging panel of experts for their invaluable time and the competing teams that have contributed so substantially to the field in submitting such excellent applications, as well as all the colleges, universities, institutions and enterprises large and small that have engaged and become involved in the competition process so enthusiastically for their strong support and rounded participation.

Mr Wandi Adriano and Dr Pasupha Chinvarasopak, Indonesian and Thai Representatives at the Knowledge Exchange Meeting

The INPUT Competition is a seed, and it is through your support and involvement in nourishing its message that has allowed this seed to break through the ground and flourish. As a reader, you may be someone who has contributed your life to the public transport industry, someone filled with accumulated knowledge and experience, someone who is bravely moving up through the industry, or simply someone new to the industry and full of passion and potential. Wherever you stand in life and in industry, it is hoped that the contents of this report have given you much food for thought and fostered inspiration in you to progress your own work and contribution to the field.

We welcome you all to coalesce around the INPUT Competition's message, and to draw on the kernels of insight and innovation offered here through the summary works of the competitions winners and finalists. Feel free to reach out to each for further information, to discuss prospects for cooperation or collaboration and to encourage more sparks!

Enterprise Award Winner Points of Contact

Place	***Name of Work***		
Applicant Enterprise Name		**Contact**	**Website / Email**
1st	***"The BIM-Based Application Platform in the Lifecycle of Urban Rail Transit"***		
Shenzhen Metro Construction Group Co., Ltd.		Huang Jizheng	www.szmc.net/szmc_en
Shenzhen Municipal Design & Research Institute		Lai Huahui	
2nd	***"High-Speed Train Intelligent Management and Information System"***		
Hong Kong Productivity Council R&D Center		Li Yu	www.hkpc.org apas_info@hkpc.org
2nd	***"Dynamic Access Control for Bus Lanes on Urban Corridors"***		
Shenzhen Municipal Design & Research Institute		Zhong Jinghan	
3rd	***"Multi-State 3D Vision Intelligent Track Inspection Robots"***		
Beijing MTR Corporation		Hou Jue	www.mtr.bj.cn/en
3rd	***"Multi-Level Rail Transit Integrated Train Control Systems"***		
Shanghai Design Institute Group		Liu Zhiping	www.smedi.com:81/index.jsp Smedi@Smedi.com
Shanghai Design Institute Group		Lei Wen	
3rd	***"Train-to-Train Communication Based on 'TACS'"***		
Fuxin Intelligent Transportation Solutions		Wang Meng	www.fitsco.com.cn/en/ info@fitsco.com.cn
4th	***"The Data Decision Brain System"***		
Zhengzhou Tiamaes Technology		Pu Xiuxia	en.tiamaes.com marketing@tiamaes.com
4th	***"Multi-Standard Communication and Edge Computing Data Services for Trains"***		
CRRC Dalian Electric Traction R&D Center		Zhang Zengyi	www.crrcgc.cc/dldgen
4th	***"Smart Rail Transit Express Inspection Vehicles"***		
Zan Rail Transit Technology		Zhang Guofu	Zanrail@126.com
4th	***"5G Digital Cockpit"***		
Senpeng Electronic Technology		Huang Huizheng	www.senptec.com

University Award Winner Points of Contact

Place	***Name of Work***		
Applicant University Name		**Contact**	**Website**
1st	***"Sustainable Concrete Materials for Transportation Engineering"***		
National University of Singapore		Du Hongjian	www.nus.edu.sg
2nd	***"Breaking the Impasse on Bus System Benefits"***		
Tongji University		Wu Mian	www.tongji.edu.cn
2nd	***"Does Asphalt Hot-Mix Recycling Provide Enough Friction"***		
Naresuan University		Korakod Nusit	www.nu.ac.th
3rd	***"Rail Surface Defect Recognition Model Based on Deep Learning"***		
Shanghai University of Engineering Science		Tong Qianqian	www.sues.edu.cn
3rd	***"Rail Fastener State Detection Method Based on Vision and Vibration"***		
Shanghai University of Engineering Science		Cui Jialiang	www.sues.edu.cn
3rd	***"Cloud-Based Ride Comfort Evaluation of Urban Rail Transit"***		
Zhejiang Normal University		Wu Jinhong	www.zjnu.cn
4th	***"Subway Train Onboard Filters"***		
Tongji University		Zang Jianbin	www.tongji.edu.cn
4th	***"Smart Multimodal Transit Mobile App and Fleet Management System"***		
Iloilo Science & Technology University (ISAT U)		Yvette G.	www.isatu.edu.ph
4th	***"Intelligent Monitoring System for Urban Rail Transit Shield Construction"***		
Soochow University		Gao Ronghuan	eng.suda.edu.cn
4th	***"ECO-Routing Strategy Design for Demand Responsive Transit Systems"***		
Dalian Maritime University		Xu Weihan	www.dlmu.edu.cn

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