Citation: ZHOU Jun, MA Liang, YANG Chao, CHEN Mingwei. System Architecture and Application Design of Shenzhen Transportation Model Under the Concept of Shared Services [J]. Urban Transport of China, 2023, 21(4): 69–76.

System Architecture and Application Design of Shenzhen Transportation Model Under the Concept of Shared Services

ZHOU Jun[1], MA Liang[1], YANG Chao[2], CHEN Mingwei[3]

1. Shenzhen Urban Planning & Land Resource Research Center, Shenzhen 518040, Guangdong, China;
2. Tongji University, Shanghai 201804, China;
3. Shanghai Chenqing Information Technology Co., Ltd., Shanghai 201206, China

Abstract: In the context of big data, developing a transportation model that can provide shared services for multiple users and scenarios is substantially challenging. Taking the third phase of the Shenzhen traffic simulation system project as an example, this paper presents an information-based simulation system architecture. The proposed architecture aims to achieve efficient shared services of the model in a complex traffic data environment. It integrates the entire process, centering on the transportation model system and leveraging multi-source traffic big data. It is supported by the automatic calibration of model parameters and planning decision indicators, with a focus on shared services of the model. Using the online transportation–land coordination system (TLCS) as an example, the paper describes the technical approach for the model shared services. It also builds an evaluation model for mesoscale multi-modal transportation, addressing two types of planning demands for stock land use: statutory graphic standards revisions (SGSV) and urban renewal planning (URP). To simplify model operation and ensure data security, the transportation model system adopts a B/S-based cloud service architecture. It offers user-side functions such as project evaluation applications, evaluation management, evaluation results, and project reviews, as well as service-side functions such as data and mapping service interfaces, middleware transfer of model and scheme data, storage and management of platform data, and simulated calls of the transportation model. The practice shows that the shared services concept has expanded the application scope of the Shenzhen transportation model system and provided better support for quantitative assessment needs for planning across multiple scenarios and users. **DOI:** 10.13813/j.cn11-5141/u.2023.0404-en

Keywords: transportation model; shared services; online evaluation; planning decision; multi-source traffic big data; Shenzhen

0 Introduction

As the world enters the era of informatization and digitization, there is a significant innovation in government governance models. Shenzhen, as a city powered by technological innovation, is committed to accelerating the construction of smart city and digital government and building the "urban brain" that supports the modernization of urban governance. The implementation of integrated data resources, government governance, and administrative services is not only a critical top-level design for achieving modern urban governance but also an important means of enhancing government management efficiency and capabilities. Urban space constitutes a vital aspect of urban governance, and the coordinated relationship between transportation and land is a core challenge in urban space governance, necessitating enhanced collaboration among government departments across various dimensions, including foundation data, model functions, and application scenarios. Therefore, the construction of a transportation model system based on the philosophy of shared services is of paramount importance for achieving high-quality governance of urban space.

The mainstream modeling framework for domestic transportation models is categorized into three levels: macro, meso, and micro [1–2]. Scholars' primary focus has been on modeling technological improvement and research related to algorithm optimization [3–4]. In recent years, although the transportation modeling field has seen exploration into shared services, the predominant emphasis remains on integrating, exploring, and analyzing multi-source traffic big data, along with short-term prediction of traffic conditions. Even though independently developed cloud computing transportation models can facilitate online evaluation of planning schemes, particularly in the context of traffic impact evaluation services [5–6], there are still issues such as insufficient refinement in the modeling process and low model precision.

Therefore, it has become a focal point in the current construction of urban transportation model systems to address the challenge of balancing the modeling precision of transportation models and shared services in a complex traffic big data environment. Taking the third phase of the

Received: 2022-08-31

Shenzhen traffic simulation system project as an example, this paper explores the establishment of a transportation model system architecture with shared services as a core concept. Besides, using two planning scenarios targeted at the urban stock development—statutory graphic standards revisions (SGSR) and urban renewal planning (URP)—this paper conducts the design of an online transportation–land collaboration system (TLCS). This aims to achieve the shared services of transportation models across multiple scenarios and users.

1 Overall architectural design of Shenzhen transportation model system

1.1 Requirements for new phase of transportation model system construction

Shenzhen was among the first cities in China to start building traffic simulation systems. From 2004 to 2006, focusing on comprehensive urban traffic management and prioritizing dynamic data collection and real-time traffic monitoring for research and development, the first phase of the traffic simulation system was completed. It integrated information collection, traffic simulation, public information, and information services into a unified traffic public information platform. Eventually, the Shenzhen traffic simulation platform was built, incorporating a data management platform, data mining analysis system, integrated transportation modeling system, multi-user transportation modeling application system, and collaborative analysis and query system for transportation and land use.

The traffic model framework of the first and second phases of the traffic simulation system mainly realized the platform integration of multi-source traffic big data and localized model calibration. Facing the demand of planning and management in the new period, for the third phase of the traffic simulation system, more attention should be paid to the core demands of spatial scale, application scenarios, and shared services of the model study, and the overall framework of the model needs to be redesigned in accordance with these demands.

1) Enhance the planning decision support for multi-modal transportation in multi-scale space

Urban circles have become the new mode for the future development of major cities, necessitating the incorporation of regional spatial scales across urban areas into transportation models. At the regional scale, transportation models should be capable of supporting major external transportation infrastructure planning, such as Shenzhen mainline railways and intercity railways. At the urban scale, they should be able to facilitate research on the integration of urban rail transit, city roads, buses, and other urban transportation in neighboring areas, as well as the layout planning of citywide logistics hubs. At the district scale, transportation models should be able to support coordinated planning of mesoscale multi-modal transportation and land use, including statutory graphic standards, urban renewal, and land readjustment. Meanwhile, in the context of carbon neutrality, the transformation of urban transportation development modes requires innovating the evaluating content of models and strengthening evaluations of the impacts of traffic noise and carbon emissions.

2) Reinforce the online evaluation of transportation models for planning scenarios like SGSR and URP

In the context of Shenzhen entering the stock development stage, the transportation model system is urgently needed to provide online evaluation tools for planning scenarios like SGSR and URP, which are crucial planning measures for addressing the shortage of development space.

3) Strengthen shared services for different user groups within the model

Designed for personnel involved in planning formulation and management, shared services of transportation models are required to deliver timely services in two aspects: conducting traffic model tool assessments for planning scheme preparation and decision-making, as well as facilitating access to query model computation results. To achieve efficient shared services in the context of a big data environment, the design of the transportation model's system architecture should involve redesigning the information process, addressing the underlying data, intermediate model, and upper-layer service from bottom to top.

1.2 Model construction concept

In response to the overall requirements of planning, coordination, and evaluation across multiple spatial scales in the Guangdong–Hong Kong–Macao Greater Bay Area, Shenzhen urban areas, and districts, a traffic simulation model has been constructed. This system, centered around the transportation model, is guided by the principles of shared services and aims for fully integrated processes. The goal is to achieve intelligent, visualized evaluations and rapid sharing of transportation and land use planning across various spatial scales, providing scientific support for urban spatial governance and decision-making in Shenzhen in the new era.

By considering the characteristics of large volumes, various types, and multi-source heterogeneity of traffic big data, as well as the requirements of rapid support for planning business, the transportation model system has been deployed on the Shenzhen government cloud platform. The integrated design encompasses four aspects: multi-source data fusion, customized mining of model parameters, construction of transportation model system, and online evaluation of planning schemes, establishing a complete technical chain of model construction and online shared services of models supported by multi-source data (Fig. 1).

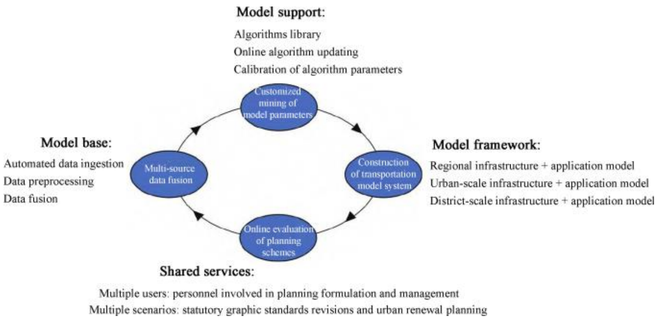

Fig. 1 Development approach for transportation model system under the shared services concept

1.3 Overall model architecture

To further enrich data mining analysis and visualize the query content for planning and decision-making needs, Finally, a 7-layered system architecture and five core subsystems have been constructed to achieve a fully integrated design process encompassing ingestion and integration of multi-source traffic big data, mining of model parameters and planning decision indicators, transportation model system construction, and shared services of transportation model. The overall system architecture of the transportation model is shown in Fig. 2.

1) Infrastructure layer: The Shenzhen government cloud platform and local servers are collaboratively used for deployment. To fulfill the requirements of integrated and intensive construction requirements of the city's information platform infrastructure, the integrated data management platform, data mining and analysis system, and visualization platform for transportation decision support (TDS) have been comprehensively deployed on the unified government cloud platform of the entire city. As the transportation model software used requires a physical key to connect to the server port, the transportation model system and the online collaboration evaluation system for transportation and land use have been deployed on local servers. These servers are connected to the Shenzhen government cloud platform through the government intranet.

2) Data layer: The integrated data management platform serves as the foundation for model construction, enabling the automatic access and management of multi-source transportation big data. The platform functions include synced data storage, data cleaning and conversion, data fusion management, data monitoring, and service monitoring.

3) Support layer: The data mining and analysis system provides support for calibrating model parameters and extracting the planning decision indicators. The parameter calibration module in the model supports the calibration of algorithm parameters of each module in the four-stage model. The planning decision indicator mining module supports the mining of urban basic indicators, transportation infrastructure evaluation, traffic operation evaluation, residents' travel characteristics, and thematic indicator evaluation.

4) Central layer: The multi-layer integrated transportation model system is the core of the entire system, playing a central role in connecting the underlying data and serving the upper application. To improve the evaluation efficiency of important high-frequency planning scenarios, new application models have been added to each layer of the transportation model, ultimately forming a transportation model system of "foundation + application" at regional, urban, and district scales. At the regional scale, the evaluation application model of major external transportation infrastructures has been constructed. At the urban scale, road transportation and urban rail transit have been modeled with two evaluation applications. At the district scale, three evaluation application models for statutory graphic standards, urban renewal, and major hub layout have been constructed.

5) Service layer: Based on the online TLCS and visualization platform for TDS, it provides shared services in two aspects: online evaluation of planning schemes and online queries for planning decision indicators. The online TLCS supports traffic demand evaluation, road transportation evaluation, urban rail transit evaluation, and traffic environmental evaluation after adjustments to planning schemes. The visualization platform for TDS supports querying current and planning indicators, as well as the forecast results of overall city demand. It also offers personalized query services such as custom queries and the generation of assessment reports.

6) Application layer: It provides decision support for regional major external transportation infrastructure planning, urban rail transit, and urban road planning, as well as SGSR and URP at the district scale. Meanwhile, this system, through interface capabilities, can offer services to other government functional departments and planning departments, realizing the shared services of professional transportation models across departments and disciplines.

7) User layer: It primarily provides services for departments such as the business offices of the Planning and Natural Resources Bureau of Shenzhen Municipality and its subordinate district administration bureaus, as well as the City Renewal and Land Development Bureau of Shenzhen Municipality (CRLDB-SZM). Additionally, it caters to the specific needs of other relevant government functional departments like the Shenzhen Municipal Bureau of Transport and the Traffic Police Bureau of the Shenzhen Municipal Public Security Bureau (TPB-SZMPSB), providing on-demand shared services to professionals in the transportation planning industry.

2 Online TLCS under the concept of shared services

Providing online evaluation for planning schemes is a direct representation of the concept of shared services of

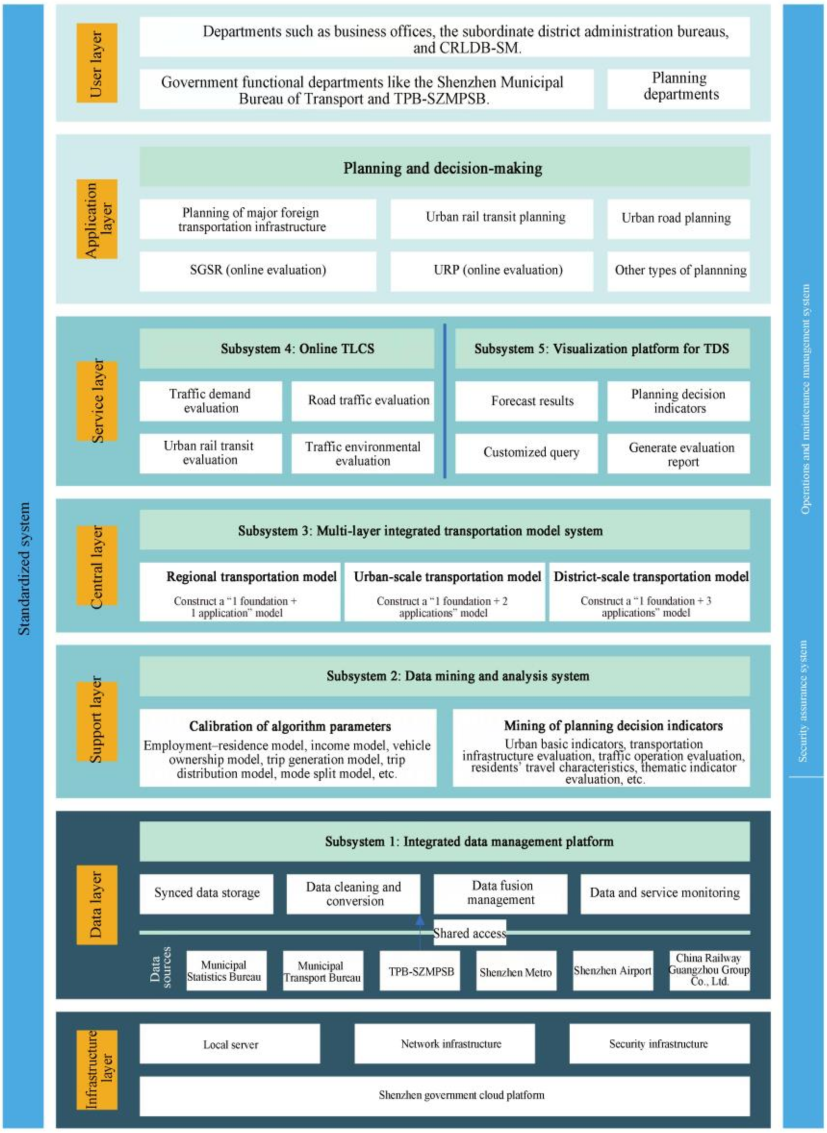

Fig. 2 General architecture of the transportation model system

transportation model. The online TLCS is designed for the online evaluation application of transportation models, specifically targeting two business scenarios: SGSR and URP.

2.1 Application requirements in planning scenarios

Urban renewal is categorized into three modes: comprehensive renovation, functional transformation, and demolition and reconstruction. Urban renewal through demolition and reconstruction typically involves adjustments to land use functions and development intensity while SGSR focuses on studying the overall scale, structure, and layout of land development within the planning scope, addressing societal and economic development demands such as residential and industrial needs.

Both URP and SGSR are carried out based on land parcels as spatial units. However, there are differences in terms of evaluation scope, evaluation duration, transportation improvement measures, and evaluation content. The evaluation range of URP is mostly less than 50 hm^2, involving fewer land parcels with the evaluation duration depending on the time frame for total project completion. Transportation improvement measures mainly focus on upgrading lower-grade roads and optimizing road nodes with the evaluation content emphasizing the impact of land development on surrounding roads and urban rail transit, etc. In contrast, SGSR generally has an evaluation scope ranging from 3 to 5 km^2, including a larger number of land parcels. The planning duration is usually for the long term, often extending to the year 2035. Transportation improvement measures may involve adjustments to urban rail transit and higher-grade road transportation, with the evaluation content predominantly focusing on transportation carrying capacity.

2.2 Underlying model of online service evaluation

The size of the transportation analysis zone is the key factor in selecting the underlying model for online evaluation. In the Shenzhen transportation model system, the sizes of regional, urban-scale, and district-scale transportation analysis zones are 84.6 km^2, 0.6 km^2, and 0.1 km^2, respectively. The SGSRand URP are all based on land parcels as the smallest research unit, and since these areas are relatively small, the district-scale transportation model is suitable as the underlying model for online evaluation.

The district-scale transportation model is considered a mesoscale transportation model, traditionally focusing primarily on road transportation evaluation. However, during the process of high-intensity and high-density development, Shenzhen faces limitations in road carrying capacity. The extent of land development is heavily dependent on the carrying capacity of urban rail transit. Consequently, there is a demand for the district-scale transportation model to support coordinated evaluation of mesoscale multi-modal transportation and land use. The district-scale transportation model, built upon the foundation of the urban-scale transportation model, refines the transportation network within the district. It employs an improved four-stage modeling approach and incorporates multiple sources of traffic big data, such as mobile signaling, urban rail transit, bus card transactions, and transportation surveys, to verify and adjust various modes of transportation. Ultimately, it establishes a mesoscale multi-modal transportation foundation model capable of fine-grained evaluation for road transportation, urban rail transit, bus transportation, etc. Besides, to ensure the logical consistency and data consistency of the transportation model system, a top-down inheritance and bottom-up feedback mechanism has been constructed: The urban transportation model is connected to the regional traffic model through the generation of attraction matrices for special attraction zones and external zones; the district-scale transportation model inherits and refines the basic network and traffic demand of the urban traffic model. Meanwhile, the updated basic network and land use planning are fed back to the integrated data management platform. The upper-layer model, when updated, obtains the latest land use and basic network data through the integrated data management platform, thereby achieving the integrated connection and dynamic update of the multi-layer model.

According to the characteristics of business needs, the research scope of SGSR is extensive. The transportation improvement measures such as adjustments to urban rail transit and higher-grade road transportation that may be involved in the compilation have a substantial impact on the external transportation accessibility of the areas covered by the planning revision, resulting in changes in travel space distribution and transportation structure. Therefore, the district-scale transportation foundation model has been selected to support the online evaluation of SGSR. The research scope of urban renewal is small, and the impact of transportation improvement measures such as low-grade road adjustment and road node optimization is relatively limited. To enhance the evaluation efficiency of URP, a lightweight urban renewal application model has been constructed by trimming the foundation model. The model employs simple algorithms such as the building generation rate method, Fratar method, and transportation mode transfer method to calculate trip generation, trip distribution, mode split, etc. The technical pathways of the urban-scale transportation foundation model and the district-scale transportation foundation model for the SGSR evaluation and the urban renewal application model for the URP evaluation are illustrated in Fig. 3.

The online evaluation function of SGSR is more flexible, although the technology involved is complex and the model computations are relatively slow. Users have the flexibility to employ various measures, including division of transportation analysis zones, setting entrance and exit connections for parking lots, adjusting the direction of roads of different grades, modifying lanes and throughput capacity attributes, altering road intersection channelization and signal timing, and adjusting the positions of stations on rail transit lines, to output a comprehensive set of indicators such as the total travel demand, spatial distribution of travel, traffic structure, passenger flow of urban rail transit, and road traffic service level. For online evaluation of urban renewal, the scope is focused on evaluating the surrounding area of a specific land parcel. To improve efficiency and reduce technical complexity, measures such as division of transportation analysis zones, adjustments to higher-grade roads, and urban rail transit are not currently available. Users can adjust the information such as land development quantity and functional structure, the direction and attributes of secondary roads, the channelization and signal timing of road intersections, and then output the detailed road evaluation indicators, such as road traffic volume, saturation, speed, intersection delay, queuing, as well as passenger flow of urban rail transit, section full load rate, and other indicators.

2.3 Online TLCS function

2.3.1 Technical framework

The online TLCS adopts a B/S-based cloud service architecture and is divided into two parts: the user side and the server side, as depicted in Fig. 4. On the user side, interactions with the system are facilitated through a Web interface, offering functions such as evaluation application, editing of land use scheme, editing of road network scheme, evaluation scheme combination, presentation of evaluation results, and multi-scheme comparisons. The server side mainly includes the business logic layer, database layer, and back-end service layer, facilitating functions like scheme

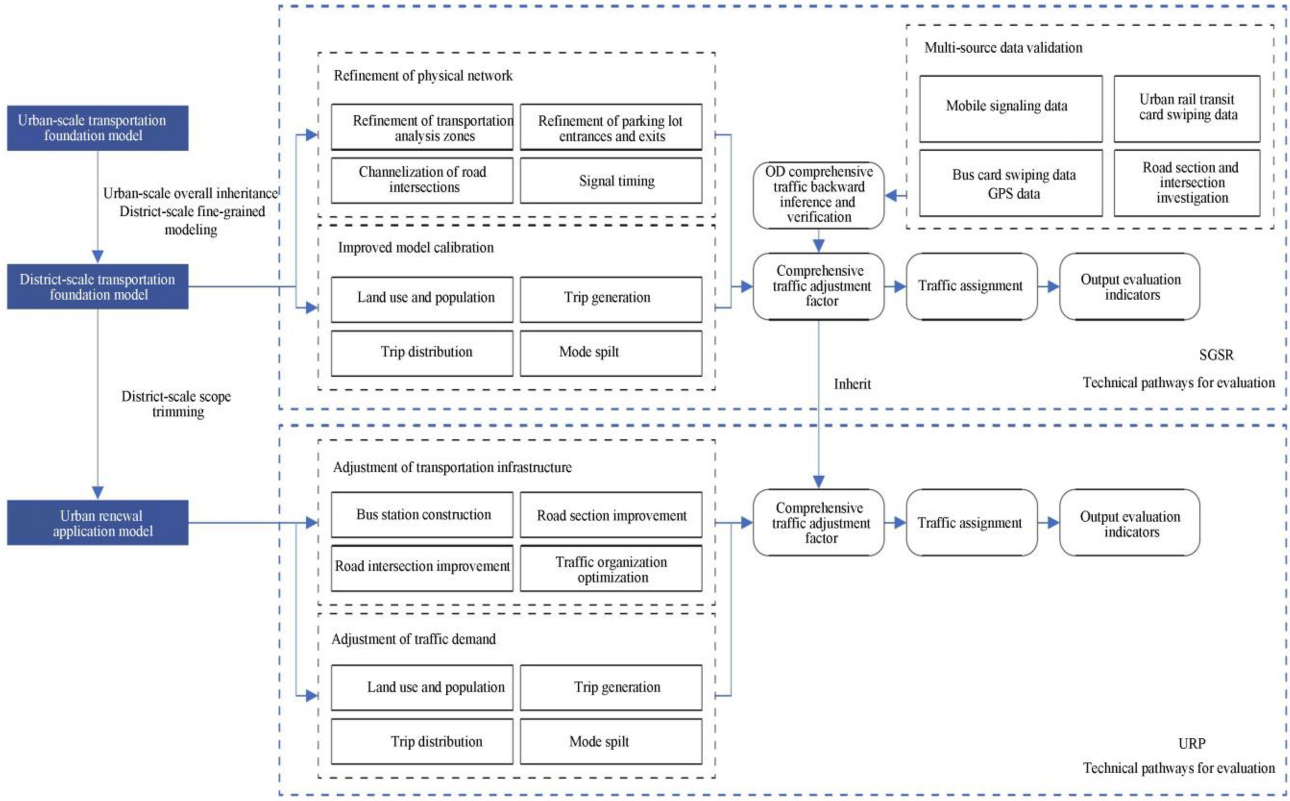

Fig. 3 Technical pathways of urban-scale and district-scale transportation foundation models

review, data transformation, calls of traffic models, and calculation of evaluation indicators.

1) Business logic layer: The core business processing layer primarily supports the handling of data requests between the system and external business systems, achieving information mobility. This includes modules for data format conversion and custom modules via COM-API.

2) Database layer: The standardized layer for front-end and back-end data interaction establishes a database standard for model basic networks, computation results, and model parameter access. It provides a unified platform for the interaction between front-end user-edited data and underlying model network data, enabling unified access to front-end user-operated data, underlying model network data, and evaluation result data.

3) Back-end service layer: This layer supports the interaction between the user-side and server-side database layers and the business logic layer. It utilizes GIS layer service interfaces to meet the user-end requirements for displaying and editing data related to road networks, land use, and zones within the analysis scope. Besides, it supports requirements for user permissions and system log management.

2.3.2 Main functions

The functional flow design of the online TLCS is illustrated in Fig. 5, comprising the following eight specific steps: user login, creation of evaluation projects, measures for planning adjustment, creation of evaluation schemes, submission of evaluation requests, visualization of evaluation results, comparison and selection of schemes, and evaluation conclusions. For planning managers, the system function flow is simplified into two steps: planning adjustment measures and creating evaluation schemes. The system retrieves information on land use schemes through an interface, enabling users to effortlessly complete the subsequent evaluation process with a single click.

1) User side

Based on the interactive Web page, the functional flow design of the online TLCS is divided into five sections on the user side: homepage, evaluation application, evaluation management, evaluation results, and project review. The homepage serves as an informational hub, presenting statistics on assessment projects and their current status, and guiding users through the evaluation process. The evaluation application section allows users to create evaluation project applications and check the status of project reviews. In the evaluation management section, users can engage in online editing and simulation operations for land planning, road networks, and urban rail transit. The evaluation results section offers visualizations of project evaluation outcomes and facilitates the comparison and selection of different schemes. The project review section, accessible to administrator users, enables the approval or rejection of evaluation projects. The visual representation of the application interfaces of online TLCS is illustrated in Fig. 6.

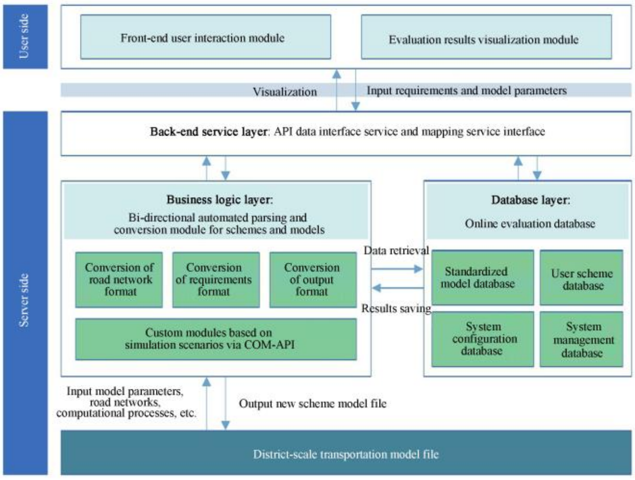

Fig. 4 Technical framework of online TLCS

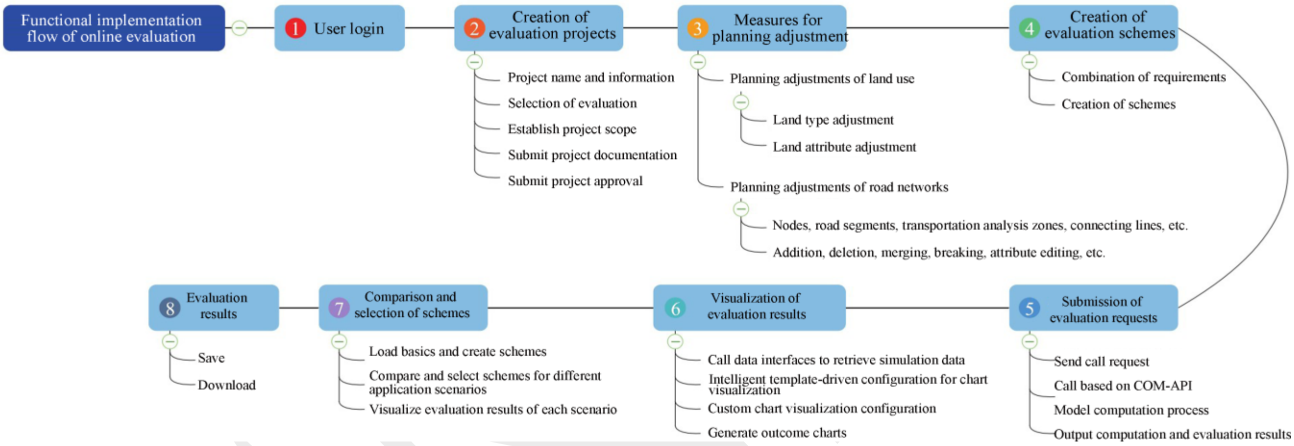

Fig. 5 Functional flow design of online TLCS

a. Homepage overview

b. Evaluation management: adjust land use planning

c. Evaluation management: adjust road network

d. Evaluation results: compare congestion levels of road networks in different schemes

Fig. 6 Example of application interfaces of online TLCS

Source of information: online TLCS of Shenzhen Municipality.

2) Server side

The server side of the system primarily serves functions including data and mapping service interfaces, middleware transfer of model and scheme data, storage and management of platform data, and simulated calls of the transportation model. The data and mapping service interface function provides corresponding service interfaces for the front-end page through standard API interfaces and the vector tile services published by GeoServer. The middleware transfer function for model and scheme data includes modules such as database standardization, conversion of road network format, demand format, and outcome format, as well as COM-API customization. This process achieves standardized and abstract modeling of land and road network data, establishing middleware data structures between user planning schemes and transportation models for bidirectional automated parsing and conversion. Using a common database as the carrier, the storage and management function of platform data categorizes and manages standardized model data, user scheme data, system configuration data, and system management data. The function of simulated calls of the transportation model, achieved through the secondary development of commercial transportation model software, automates the process from user planning schemes to the output of traffic model simulation results. These results are then stored in the platform database, ready for utilization in visualizing evaluation outcomes on the front end.

2.4 Key features and innovations

The online TLCS, built on the concept of shared services, represents an innovative application practice of "Internet + transportation models." It aims to explore the technical pathway for transitioning specialized transportation models from back-end planning to the front-end. The system exhibits the following features in terms of technical framework, foundation models, and the construction of intermediate conversion databases.

1) Introduction of B/S cloud service architecture with a simultaneous focus on shared services and data security of transportation model

The expertise required for traffic models and concerns about data security are significant barriers to their widespread application. By introducing B/S cloud service architecture, the system is divided into two main components: the user side and the server side. The user side, presented as a Web page, offers a user-friendly interactive experience, lowering the barrier for model application without the need for users to install professional software or a client locally. The server side, driven by front-end user operations, performs model simulation calculations in the background, avoiding direct model access. This ensures model data security while guaranteeing a positive user experience.

2) Construction of a mesoscale multi-modal transportation evaluation model to support detailed evaluations for stock land use planning

The planning of stock land use demands a comprehensive evaluation of transportation capacities across various modes like urban rail transit and road transportation at the land-parcel scale. Traditional models require the collaborative evaluation of macroscale and mesoscale models, leading to technical complexity and low evaluation efficiency. The district-scale transportation model constructed in this paper, while fully inheriting the urban-scale transportation model, conducts detailed modeling within the scope. It involves the improved four-stage modeling method, covering all transportation networks, including urban rail transit and road transportation. This achieves the reconstruction of the technical pathway for a mesoscale multi-modal transportation evaluation model, effectively supporting detailed evaluations of stock land use planning.

3) Construction of a standardized model database compatible with calls to mainstream transportation modeling software

Changes in calling interfaces resulting from variability in software versions can affect system stability. Based on combing the common operations of planning, a set of standardized model intermediate databases has been established to realize the standardized storage of common data such as transportation networks and transportation analysis zones. Serving as a bridge, the intermediate database is responsible for storing the front-end user operation information and transmitting these operations to the underlying model, as well as retrieving the calculation results. In the case of changes in the software interface, only the intermediate database needs to be adapted to the model interface to ensure the system's compatibility with the current mainstream transportation model software, ensuring system stability and scalability.

3 Conclusion

Shared services are an important development direction for transportation models to play a continuing role in government planning and decision-making. To achieve efficient shared services of models in a complex transportation data environment, the bottom-up information flow redesigning of "underlying data–middle model–upper service" was implemented in this paper, utilizing the third phase of the Shenzhen traffic simulation system as an example. In this paper, an integrated simulation system architecture was constructed based on a data platform, supported by a data mining analysis system, with the transportation model serving as the central core. It also incorporates the online TLCS and the visualization platform for TDS as application services. The online TLCS serves as the direct carrier for shared services of transportation models. This paper presents online evaluations for SGSR and URP as examples, covering the introduction of application requirements for planning scenarios, underlying model design, system technical framework, main functions, and system features. The practicality of transportation models is a crucial driving force for the continuous development of the Shenzhen transportation model system. Further exploration of online evaluation services of transportation models in more planning scenarios and advancements in new technologies will be incorporated to continuously improve the technical methods of the models, enabling transportation models to play a greater role in urban spatial collaborative governance.

References

[1] LU X M, CHEN B Z, DONG Z G. Conception and outcomes: the Shanghai comprehensive transportation model system [J]. Urban Transport of China, 2008, 6(1):13–18. (in Chinese)

[2] LI C Y, CHEN J C, GUO J F, et al. Selected urban transportation models [J]. Urban Transport of China, 2008, 6(1):32–49. (in Chinese)

[3] SHE S Y, ZHENG M, XIANG Y L, et al. Aggregate tour-based model framework of urban transportation [J]. Urban Transport of China, 2021, 19(6):91–101. (in Chinese)

[4] CHEN X L, CHEN X H. Study on a simplified activity-based model framework based on stability of travelers [J]. Journal of South China University of Technology (natural science edition): 2021, 49(2): 59–67. (in Chinese)

[5] WU K H, WANG R, GAO C, et al. Research on the construction methods of a big data platform for urban transportation planning [C]//Urban Transportation Planning Academic Committee of China Urban Planning Society. Quality Transportation and Collaborative Governance: Proceedings of the 2019 China Urban Transport Planning Annual Conference. Beijing: China Architecture & Building Press, 2019: 424. (in Chinese)

[6] ZHANG X C, LIN T, DUAN Z Y, et al. Big Data computing platform for urban transportation governance TransPaaS [M]. Shanghai: Tongji University Press, 2021. (in Chinese)

