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Regulation Strategies for the Red Line Planning of Major Road Network in Guangzhou under the Territorial Spatial Planning System

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Abstract: As a critical link between municipal-level territorial spatial master planning and regulatory detailed planning, the regulation of red line planning of major road network enhances communication and coordination across different planning frameworks, enabling standardized, refined, and systematic management of planned roads. This paper outlines the planning regulation requirements for major roads under various planning systems in Guangzhou, highlighting the need for greater control and spatial protection for the planning of major roads under the territorial spatial planning framework. It argues that the red line of major road network should serve as a key component for precisely translating strategic intentions of territorial spatial planning to regulatory detailed planning. Based on an analysis of the current planning and regulation status regarding the red line of major road network in Guangzhou, this paper proposes the establishment of a planning regulation system for the boundary line of major road network within the context of territorial spatial planning. This paper focuses on three key areas: 1) developing a transmission mechanism for red line planning regulation of major road network; 2) constructing data infrastructure that links territorial spatial master planning and regulatory detailed planning; and 3) formulating rules for adjusting red lines of major road network. Practices in Guangzhou demonstrate that the system can effectively enhance transmission and coordination across different planning frameworks, promote a high-quality development of urban road planning, and achieve the planning goal of "maintaining one blueprint throughout the entire process".
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Keywords: territorial spatial planning; road planning; red line of major road network; planning regulation; transmission mechanism

0 Introduction

As the transportation infrastructure with the largest proportion of land use in urban areas, the road is the backbone connecting urban land and serves various transportation needs. The Outline of National Comprehensive Three-dimensional Transportation Network Planning proposes that the main framework of the transportation network is composed of the most critical line network, which is the main axis supporting the territorial spatial development and protection, and the backbone network with the highest efficiency and intensity in resource allocation of various transportation modes [1]. The Standard for Urban Comprehensive Transportation System Planning (GB/T 51328–2018) divides the urban road into three major categories based on its functions: the trunk road, the branch road, and the distribution road connecting the two. Among them, the trunk road includes the expressway and the main road, which is the urban major road network, mainly serving long-distance motorized transportation and connecting the main functional areas [2]. On this basis, Guangzhou refers to highways, expressways, main roads (except for Class Ⅲ main roads) and their interchange nodes within urban areas that meet the requirements of functional positioning, cross-sectional layout, and regulatory standards as the major road network.

Under the urban planning system, road planning mainly clarifies the functions and directions of the major road network, but there is a problem of insufficient regulation depth. In 2020, the General Office of the Ministry of Natural Resources issued the Guidelines for the Preparation of the Municipal Territorial Spatial Master Plans (Trial), which requires that the regulatory scope of important transportation facilities should be determined in preparing the municipal territorial spatial master plan. It solves the problem of insufficient depth of road planning and regulation under the urban planning system to some extent, but also brings a new challenge: how to transmit the strategic intention of the municipal territorial spatial master plan to the regulatory detailed plan.

Qian et al. [3] proposed that the comprehensive transportation system planning, special transportation planning, and detailed transportation planning at different spatial levels should be based on the overall framework of "what to manage, what to plan, and what to approve". Deng et al. [4] clarified the regulation elements and transmission requirements of transportation facilities under the territorial spatial planning system at all levels, and explored a

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transportation planning system that can adapt to the requirements of territorial spatial planning and achieve linkage at the city and district levels. In the overall territorial spatial planning at the city level, transportation facility planning focuses on macro, strategic, and global aspects. In the overall territorial spatial planning at the district level, transportation facility planning focuses on implementing the requirements and strategic arrangements of the overall territorial spatial planning at the city level. Ma et al. [5] used the practice in Guangzhou as an example to explain the organizational methods, technical concepts, and expression forms of transportation planning in territorial spatial planning, and summarized the experience of synchronously formulating transportation planning and establishing a professional, efficient, and dynamic maintenance system in territorial spatial planning. Wang et al. [6] reviewed the existing regulations and research on planning transmission and regulation, proposed transmission modes between different levels of transportation planning and between transportation planning and territorial spatial planning, and summarized the main regulation methods for the specific content of transportation planning.

In summary, existing research mainly focuses on establishing a transmission mechanism for territorial spatial planning from the perspective of the entire urban transportation system, which limits the depth of research on road planning. In addition, existing research focuses on the division of powers for different levels (city and district) and types of transportation planning, clarifying corresponding regulatory elements and forms, mainly answering the question of "what to manage", but not solving the question of "how to manage". In practice, the limitations of the depth of research on the overall planning of municipal territorial space have led to a "surplus of rigidity and insufficient flexibility" in the planning blueprint. Therefore, it is necessary to find a balance between the authority of higher-level planning and the practicality of regulatory detailed planning, which not only accurately conveys the strategic intent of the overall planning of municipal territorial space, but also retains sufficient flexibility for the implementation of regulatory detailed planning. Therefore, taking Guangzhou as an example, this paper focused on the red line of the major road network to explore the road planning and regulation path under the territorial spatial planning system, thereby achieving standardization, refinement, and systematization of planning and regulation.

1 Requirements for planning and regulation of major road network in Guangzhou under different planning systems

1.1 Urban planning system

After years of collaborative efforts, Guangzhou has basically formed a road planning system that corresponds to the urban planning system. In view of different types of planning and requirements in the urban planning system, road planning that matches its content and depth has been carried out and incorporated into various types of planning (see Fig. 1).

1) At the level of the overall urban planning outline, road planning focuses on clarifying the macro development directions, goals, and strategies, with a particular emphasis on determining the structure of the urban road network, spatiotemporal goals, and transportation volume targets.

2) At the level of overall urban planning, road planning plays a core role, mainly defining the functional positioning and spatial direction of the major road network, and proposing systematic planning schemes for important passages.

3) At the level of regulatory detailed planning, road planning mainly clarifies the requirements for controlling road red lines, implementing road line positions, grades, widths, coordinates, cross-sectional forms, and layout forms of important interchange nodes.

4) At the level of detailed planning for construction, road planning mainly refines the scale of roads, as well as the design schemes for road sections and nodes [7].

1.2 Territorial spatial planning system

1.2.1 Road planning and regulation system

Under the territorial spatial planning system, the road planning and regulation system in Guangzhou (see Fig. 2) mainly divides powers based on the road grade.

1) In the overall territorial spatial planning at the city level, it focuses on major road traffic facilities, and the main regulatory elements include highways, expressways, and main roads. The regulation content includes functional levels, line positions, widths, interchange nodes, and road red lines (the land use regulatory scope).

2) At the district level of overall territorial spatial planning, on the premise of strictly implementing the regulation requirements of overall territorial spatial planning at the municipal level, for projects with implementation difficulties, coordination can be made with the overall territorial spatial planning at the municipal level according to the actual situation, and adjustments and feedbacks can be done. The main regulatory elements include highways, expressways, main roads, and secondary roads, and the regulation content includes functional levels, line positions, widths, interchange nodes, and road red lines (the land use regulatory scope). For branch roads, it is not necessary to control the depth of the road red line, but the road line position should be clearly defined.

3) At the level of regulatory detailed planning, it mainly focuses on implementation and requires regulation over all levels of roads at the road red line level.

1.2.2 Requirements for planning and regulation of the major road network

Under the national spatial planning system, Guangzhou has introduced a major road network planning and regulation

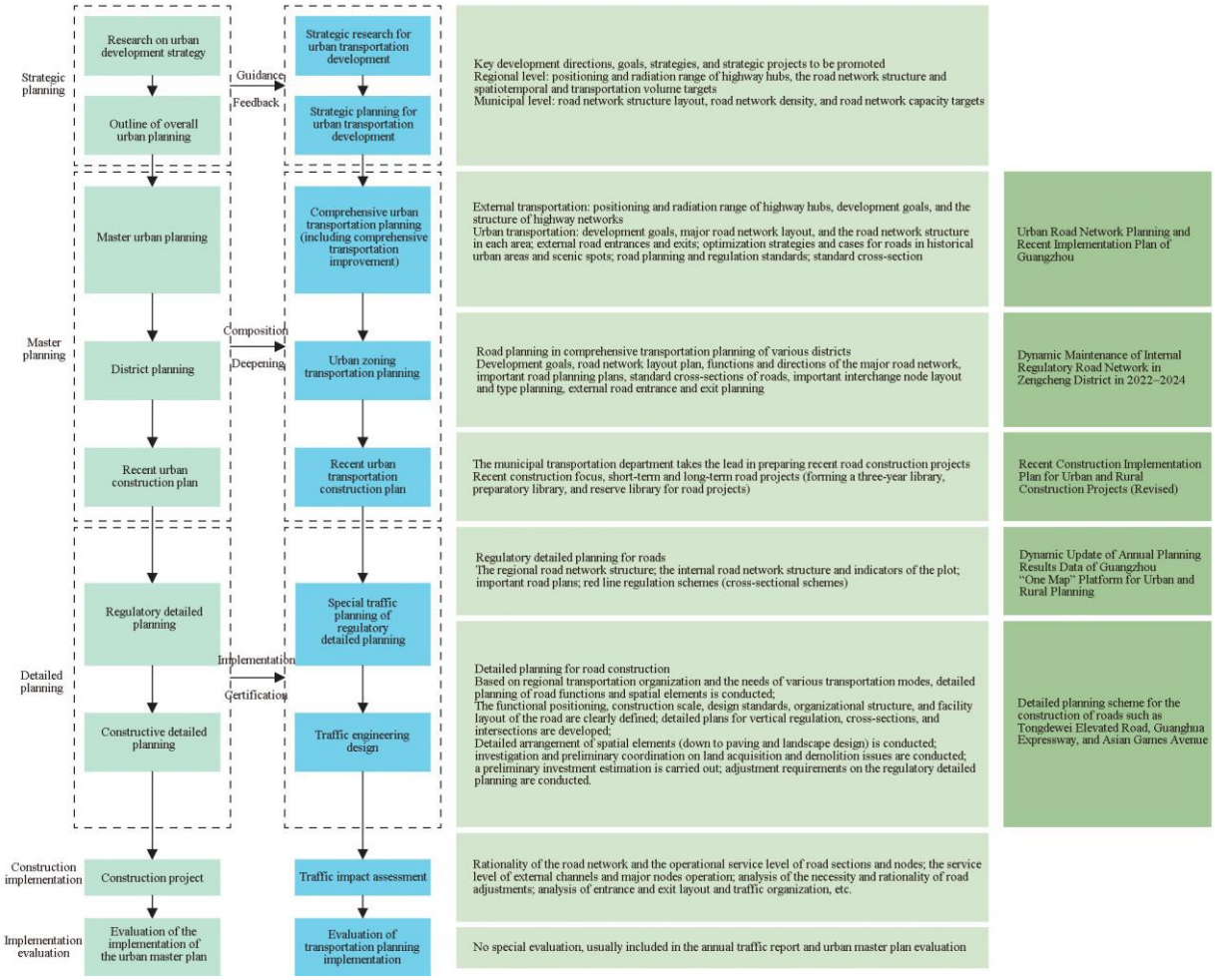


Fig.1 Key content of road planning under Guangzhou's urban planning system

Source: Ref. [7].

system in road planning, which adds a regulatory link between the overall national spatial planning and the regulatory detailed planning. Compared with the urban planning system, the requirements for the planning and regulation of the major road network in the territorial spatial planning system are as follows:

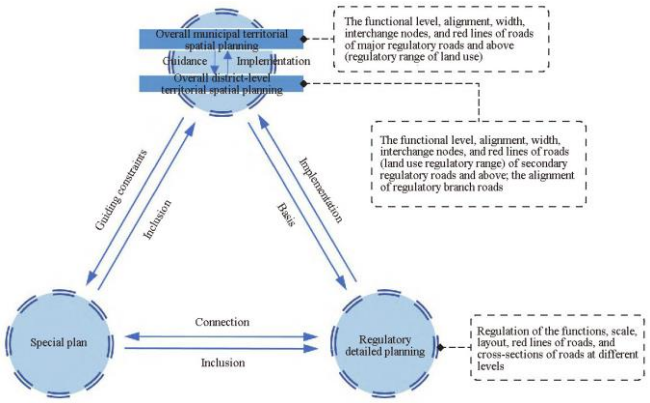


Fig. 2 Road planning regulation framework of Guangzhou under the territorial spatial planning system

1) Road planning and regulation is deepened

Under the urban planning system, the road planning of the overall urban planning mainly clarifies the network layout of the major road network in the urban area, and controls the direction of road lines in a single line form. The Guidelines for the Compilation of Municipal Territorial Spatial Overall Plans (Trial) clearly stipulate that the compilation of municipal territorial spatial master plans needs to determine the regulatory scope of important transportation facility land, delineate the yellow line regulatory area of important infrastructures in the central urban area, and coordinate with the ecological protection red line, permanent basic farmland and other regulatory lines. Therefore, the overall planning of municipal territorial space has significantly strengthened the regulation depth of road planning, and the regulatory form has shifted from the regulatory line position of a single line to the regulatory land of the designated area.

2) The guarantee of the land use space is strengthened

Under the urban planning system, due to the excessive types of planning and overlapping conflicts in the content, the efficiency of spatial resource allocation is low, which is not

conducive to the scientific layout of production, life, and ecological spaces, and the implementation of planned roads is difficult. The territorial spatial planning system integrates the planning of main functional areas, land use planning, and urban-rural planning to form a unified territorial spatial planning "one map" platform. Therefore, the major road network planning under the territorial spatial planning system pays more attention to the bottom line constraints such as red lines for ecological protection and permanent basic farmland, significantly improves the guarantee degree of the land use space, enhances the feasibility of planning implementation, and is more conducive to realizing the planning blueprint.

In summary, under the territorial spatial planning system, more attention should be paid to the depth of regulation and spatial guarantee of the major road network planning, seeking a balance between rigid regulation and flexible adjustment to ensure that road planning is both binding and adaptable to future changes. Meanwhile, the strategic intention of territorial spatial planning will be accurately transmitted to the regulatory detailed planning, achieving an organic connection from macro layout to micro implementation. Due to that the red line of the road is the focal point of regulatory detailed planning, this paper focuses on the red line of the major road network to explore the planning and regulation strategies of the red line of major road network.

2 Current situation of planning and regulation of the red line of the major road network

2.1 Unclear upper-level planning transmission mechanism

It is crucial to establish a practical and feasible planning and regulation transmission mechanism for improving the overall efficiency of the major road network planning. The overall territorial spatial planning of Guangzhou at the municipal and district levels has been approved, and the approval management system for detailed regulatory planning has become mature. The preparation of special plans is progressing in an orderly manner, and the system for preparing territorial spatial planning has been basically established. However, under the current road planning and regulation system, there is a lack of efficient connection between the regulation objects and contents of different levels and types of planning. It is urgent to give full play to the leading role of the overall municipal territorial spatial planning, and explore practical and feasible transmission mechanisms for the planning, regulation and transmission of the major road network, thereby accurately transmitting their planning intentions to regulatory detailed plans, and achieving precise planning and regulation of the major road network through the red line of roads.

2.2 The inclusion of the red line scheme of the major road network in the regulatory detailed planning lags in terms of timing

The adjustment of the red line of the major road network needs to be coordinated with the legally regulatory detailed planning map. The regulatory detailed planning adjustment process in Guangzhou includes planning preparation, scheme publicity, scheme review, meeting deliberation, result approval, and issuing data on the Internet. However, due to frequent adjustments to the major road network project plan and long approval cycles, there is a lag in incorporating the red line plan into the regulatory detailed planning management for the major road network with unclear implementation timelines (such as phase Ⅲ of the Linjiang Avenue and the Zengfo Expressway), which cannot effectively guide the adjustment and preparation of regulatory detailed planning around the major road network project.

2.3 The red line of the major road network lacks systematic adjustment

The adjustment of red lines of roads can be divided into two categories: One is proactive adjustment, mainly referring to the regulatory detailed planning adjustment independently carried out by key road engineering projects, and such adjustments are usually carried out according to the needs of the project; The other type is passive adjustment, mainly referring to the adjustment of red lines of roads due to changes in the land layout during the preparation, revision, and adjustment process of regulatory detailed planning. The situation of passive adjustment is more common, and its limitation is that it can usually only adjust the red line of the road within the planning scope, without fully considering the systematic role of the major road network in the regional traffic function and the road network structure, and it can easily lead to the fracture of the road network function. The current regulatory detailed planning lacks clear access conditions, demonstration requirements, and procedural regulations for adjusting the red line of the major road network, resulting in arbitrary adjustments in practical operations, which affects the layout and implementation effect of road functions, and may even lead to problems such as reduced traffic capacity and poor traffic connectivity.

3 Strategies for red line planning and regulation of the major road network

3.1 A regulatory transmission mechanism for red line planning of the major road network is established

The planning of the red line of the major road network is essentially a special planning content, and the major road

network involved comes from the overall municipal territorial spatial planning, the overall district territorial spatial planning, relevant special planning, and regulatory detailed planning. Various plans are directly connected through underlying data, which can strengthen the transmission and collaboration between different plans, and help solve problems such as unclear transmission mechanisms in upper-level planning, lagging timing of including the red line scheme of the major road network in the regulatory detailed planning, and a lack of systematic adjustment. At the macro level, the red line of the major road network inherits the strategic intention of the municipal overall territorial spatial planning, which can achieve regulation over a city's overall road network pattern and support the development of the urban spatial structure. At the micro level, as the basis for regulatory detailed planning adjustments, the red line of the major road network can effectively transmit the regulatory intention of the overall municipal territorial spatial planning to the regulatory detailed planning (see Figs. 3 and 4).

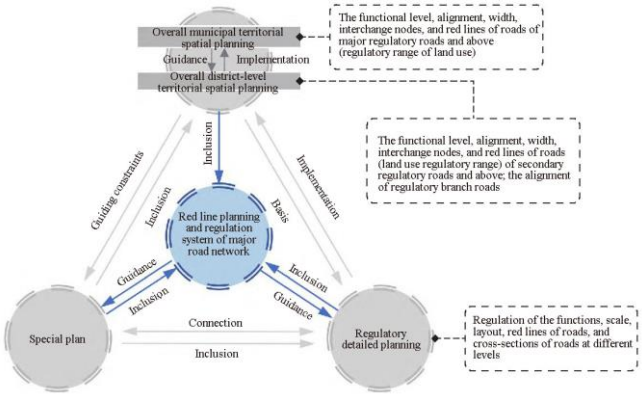


Fig.3 Illustration of the transmission mechanism in the red line planning regulation system for Guangzhou's major road network

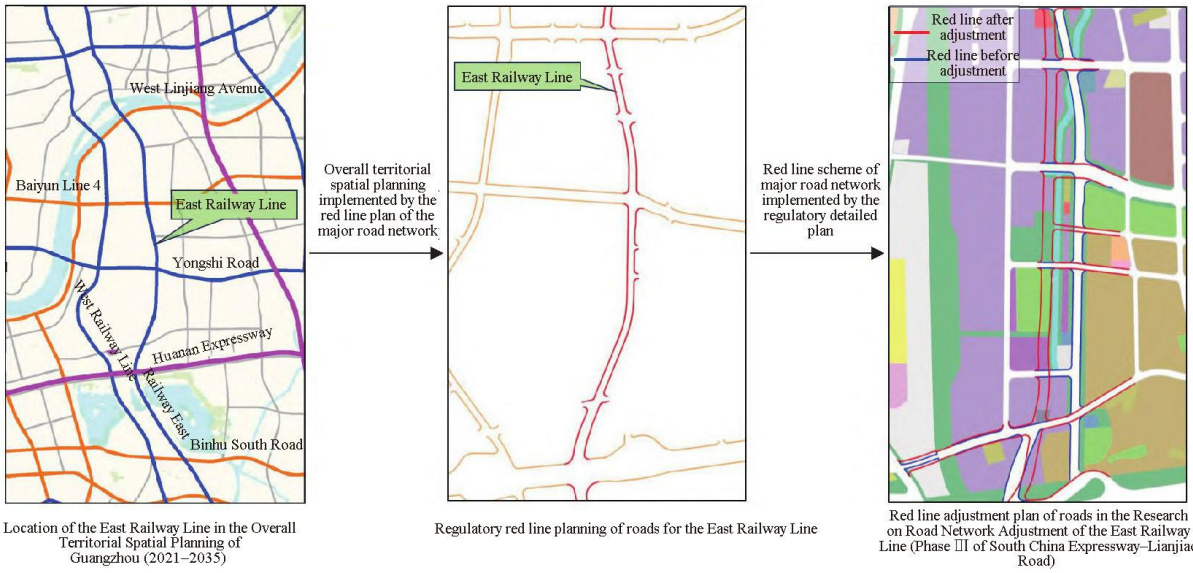
3.2 The data base for the red line of major road network is built

The integration of the red line data of the major road network is guided by the overall municipal territorial spatial planning and based on the regulatory detailed planning. When the regulatory detailed planning of the red line of roads is consistent with the road line of the overall city-level territorial spatial planning, it can be directly included in the red line of the major road network. When the two are inconsistent, it is necessary to conduct research in the overall district level territorial spatial planning, focusing on the feasibility of the major road network in terms of planning constraints, natural conditions, land ownership, and demolition costs. The regulatory method of the red line for a single major road network can refer to Ref. [8]. research on the overall district level territorial spatial planning has formed a red line scheme of stable, reasonable and feasible major road network, which has been incorporated into the red line of the major road network and ultimately formed a data base (see Fig. 5).

After integration, the red line of the major road network in Guangzhou is 7 414 km, including 1 633 km of highways, 1 280 km of expressways, and 4 501 km of main roads. The proportion of implementing regulatory detailed planning of red lines of roads is 72%, that of implementing overall municipal spatial planning of red lines of roads is 4%, and that of implementing overall district-level territorial spatial planning of red lines of roads is 24%.

3.3 Rules for adjusting the red line of the major road network are developed

As the basis for road standardization, refinement, and systematic management and regulation under the territorial spatial planning system, the red line of the major road



Location of the East Railway Line in the Overall Territorial Spatial Planning of Guangzhou (2021–2035)

Regulatory red line planning of roads for the East Railway Line

Red line adjustment plan of roads in the Research on Road Network Adjustment of the East Railway Line (Phase Ⅱ of South China Expressway–Lianjiao Road)

Fig. 4 Representative case of the transmission mechanism in the red line planning regulation system for Guangzhou's major road network

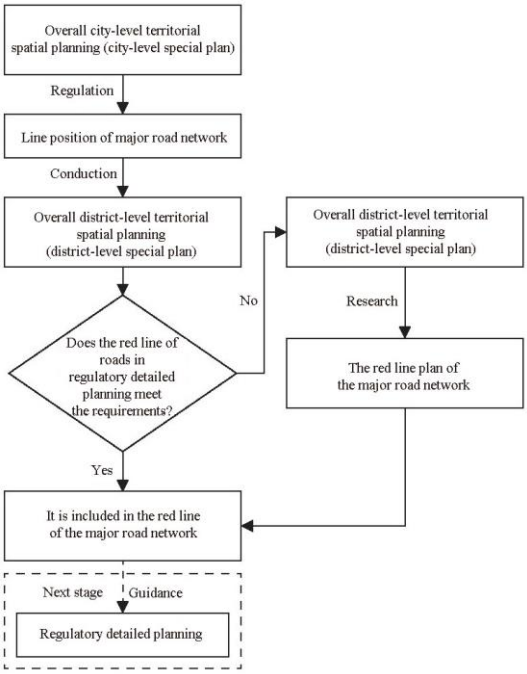


Fig. 5 Workflow for data infrastructure development for the red line of major road network in Guangzhou

network needs to be dynamically maintained in combination with the needs of land development, current conditions, and planning requirements. Therefore, Guangzhou has formulated rules for adjusting the red line of the major road network to guide the subsequent preparation of relevant special plans and detailed regulatory plans.

1) Adjustment of access status for the red line of the major road network

The adjustment of the red line for the major road network in Guangzhou is shown in Fig. 6. In the stage of preparing the detailed regulatory plan, the red line of the road can be optimized and adjusted due to the modification of the detailed regulatory plan or the demonstration of road planning conditions carried out due to the implementation of the major road network construction. If other detailed regulatory plans are necessary due to adjustments in urban spatial layout, compliance with natural conditions and ownership land conditions, or avoidance needs, the red line of the major road network can be optimized and adjusted while ensuring the reasonable structure of the major road network, no reduction in the function and traffic carrying capacity, no increase in the implementation difficulty, and that it is smoothly connected with the surrounding road network.

In the stage of formulating special transportation plans, due to the needs of urban development and road planning and construction, the planning and natural resources authorities can organize and carry out city/district-level comprehensive transportation planning, city/district-level road planning, cross administrative planning of road connection, road planning of key areas, and important road route selection planning, which can optimize and adjust the red line of the major road network.

2) Classification of adjustment situations

The adjustment range of the red line of the major road network may vary during the process of special planning and regulatory detailed planning. To achieve refined regulation and improve the administrative approval efficiency, the adjustment of the red line of the major road network is divided into two categories: major adjustments and minor adjustments. Major adjustments mainly involve the addition or removal of the major road network, adjustment of line positions, that of grades and widths, and that of land and functions for interchange nodes (see Fig. 7). Except for major adjustments, other minor adjustments have a relatively small impact on the traffic function of the major road network, mainly manifested as local adjustments to the red line of the major road network.

3) Adjustment process optimization

In the stage of regulatory detailed planning, projects involving significant adjustments to the red line of the major road network require technical demonstration, which mainly includes: comparative analysis of the pre- and post-adjustment plans, and discussing the necessity of adjusting the red line of roads in combination with relevant planning, urban development spatial layout, and land development and utilization factors. The feasibility needs to be evaluated from the aspects of engineering feasibility, historical approval status, planning coordination, difficulty in land acquisition and demolition, opinions of relevant ownership units, and analysis of the adjustment impact, and conclusions should be drawn. Meanwhile, in the existing regulatory detailed planning review and approval process, an expert argumentation meeting or review meeting should be added to review and adjust the plan (which can be merged with the expert review process of regulatory detailed planning). The optimization and adjustment plan that has been fully demonstrated should be included in the submission for review of the regulatory detailed planning results (see Fig. 8). For minor adjustments, it is necessary to supplement the explanation of the adjustment of the red line of the major road network in the regulatory detailed planning results and include it in the submitted matters for review. The major and minor adjustments during the special planning stage shall be carried out in accordance with the supplementary procedures for the regulatory detailed planning stage (see blue text in Fig. 8).

4 Conclusion

This paper explored the red line planning and regulation strategies for the major road network in Guangzhou under the territorial spatial planning system. As a link between the

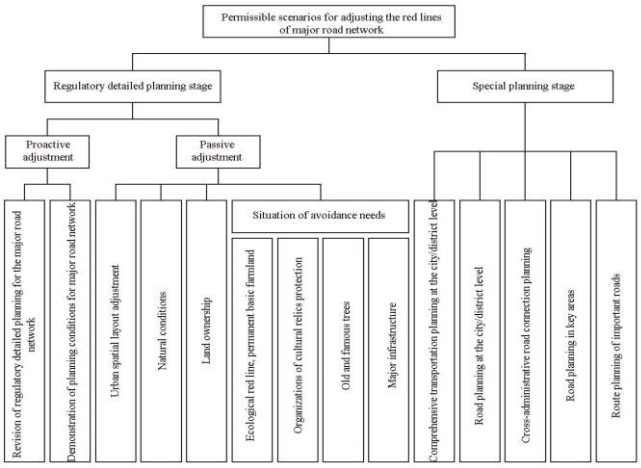


Fig. 6 Permissible scenarios for adjusting red lines of major road network in Guangzhou

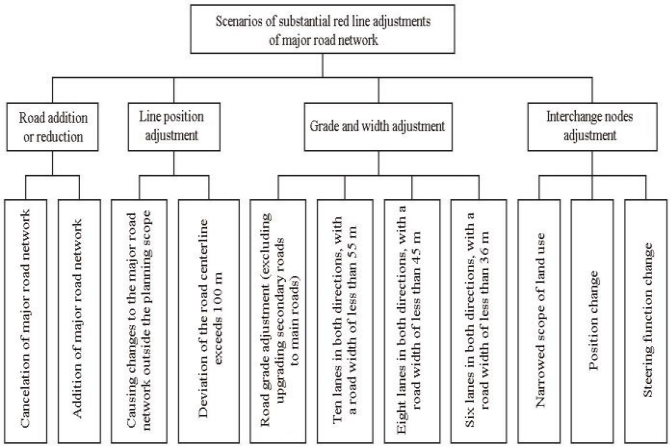


Fig. 7 Scenarios of substantial red line adjustments of major road network in Guangzhou

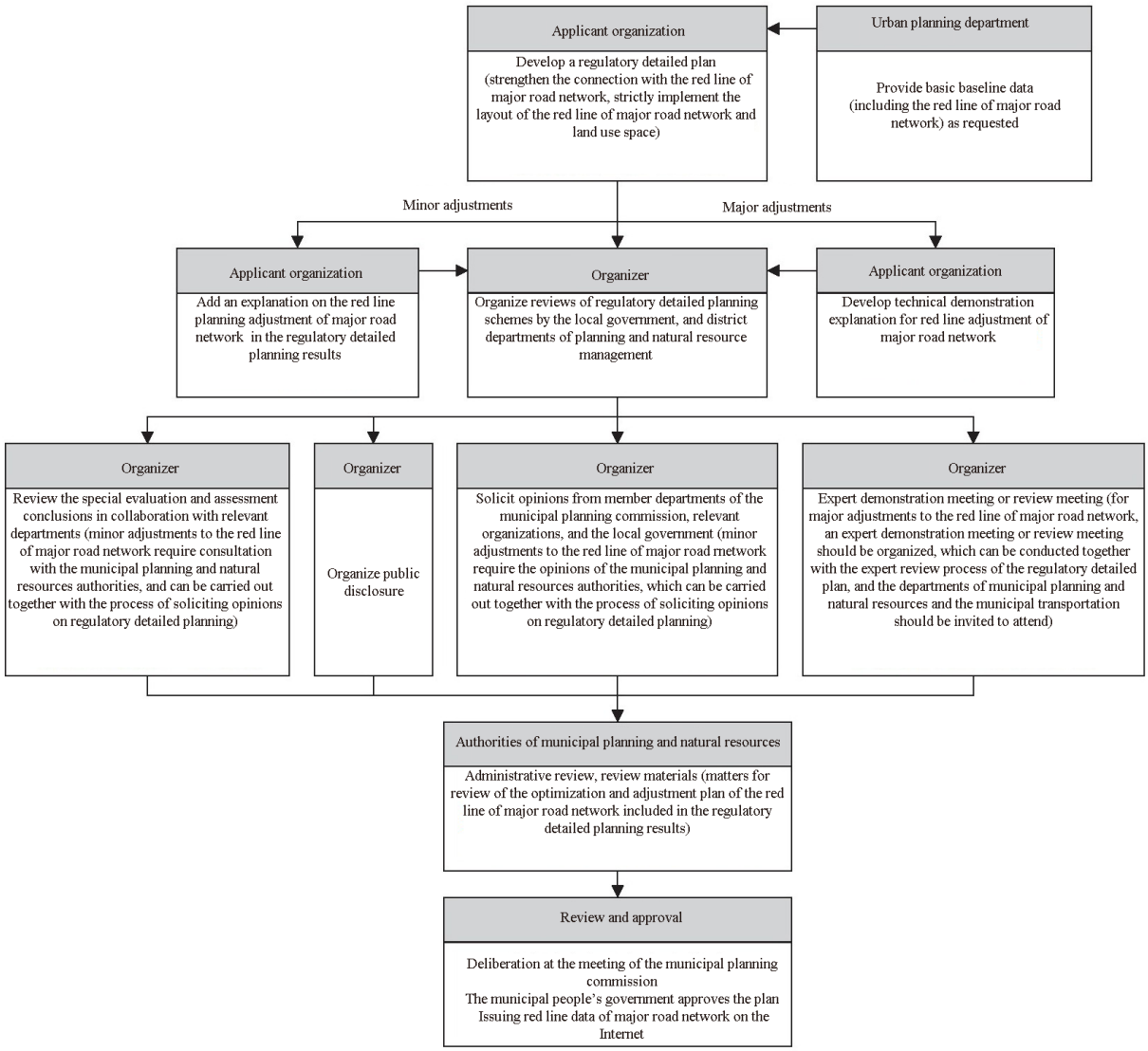


Fig. 8 Procedures for adjusting red lines of major road network in Guangzhou

Source: Ref. [9].

overall municipal territorial spatial planning and the regulatory detailed planning, the red line of the major road network strengthens the transmission and coordination between different levels and types of planning, realizes the standardization, refinement, and systematic regulation of planned roads, and embodies the concept of rigid and flexible planning and regulation. At present, the overall territorial spatial planning at the municipal and district levels in Guangzhou has been approved, and the red line regulation system for the major road network will systematically and scientifically guide the preparation of regulatory detailed plans. The relevant results have been included in the administrative review and approval procedures of Guangzhou.

Future research will focus on the development of the intelligent decision support system. Based on the GIS data platform, machine learning algorithms will be used to construct a quantitative evaluation model for the red line scheme of the major road network, achieving intelligent recognition of the rationality for the adjustment of the red line of the major road network, thereby improving the administrative approval efficiency.

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