A Study on the Selection of Technical Standards for Highways in Remote Western Areas

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Abstract: Selecting highway technical standards affects investment decisions, construction scale, and transportation organization. The article takes the Shanshan-Kumish highway construction project as a dependent project, and in order to make the project meet the requirements of regional development and maximize economic benefits, the selection of technical standards should be carried out first. By exploring the principles of selecting technical standards for highways in remote areas in the West and the factors influencing them, a logical framework is constructed from three dimensions of demand, decision-making, and conditions, and a comparative study is proposed with the level of service, structural form, and construction program as the main indexes. The method of selecting the primary technical standards in highway construction explained in the research process can provide a reference for selecting projects in similar areas.

Keywords: road construction; western region; logical framework; program must be selected

1 Introduction

With the Belt and Road Initiative and the new era of Western development, infrastructure projects in remote areas of the West have reached their construction zenith. As a "large dispersion and small agglomeration" urban development pattern in the western region, the highway transportation mode is mobile and flexible in constructing a high-efficiency backbone network, high-quality rapid network, convenient trunk network, and wide-coverage primary network. This mode requires lower project investment, boasts a rich construction standard system, and plays an apparent role in the essential spatial support of industrial linkage[1]. Highway projects are better suited for the remote western regions with vast land and complex terrain.

When carrying out feasibility studies for highway construction, priority should be given to determining the technical standards of the highway because the choice of technical standards directly affects the investment decision of the highway, the scale of construction, and the organization of traffic. Similar studies are mainly based on case studies, and this paper takes the S24 Shanshan-Kumish expressway construction project as the basis to conduct a study on the selection of technical standards for highways in remote areas in the West.

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2 Project Overview

The S24 Shanshan-Kumish Expressway Construction Project is situated on the northwestern border of China, located explicitly in Gaochang District, Toxun County, and Shanshan County of Turpan City, Xinjiang Uygur Autonomous Region - a uniquely multi-ethnic area. The route spans 182.401 km, from the starting point at the construction between Shanshan Interchange and Lianmuqin Interchange of the G30 line to the endpoint near Kumish Town of the G3012 line, facilitating a convergence of multiple religions and cultures. The project serves as a crucial connection between the G30 and G3012 trunk road networks in Xinjiang and acts as a backbone for Turpan's comprehensive transportation system, thereby boosting mineral resource development and optimizing the regional road network. Cultural disparities, geographical location, resource allocation, and distinct economic development backgrounds form the social and pragmatic foundation for constructing highways in remote western regions.

Currently, vehicles traveling in and out of Xinjiang region predominantly use the G3012 road through Turpan City and then follow the G30 towards the Gansu territory. These two routes form the primary road network within the region. While the overall design standard is high, the Gan ditch road section, about 86km, presents some challenges. Owing to the intricate topographic milieu and premature development of the social-economic status, the standard construction speed of 60km/h for this road segment employs numerous small radius curves, thereby exacerbating the prominent longitudinal slope throughout. The average longitudinal slope measures 3.3%, while the maximum longitudinal slope reaches 6%. The construction standards mandate a speed limit of 60km/h on this road section due to the abundance of small radius curves. The entire stretch of the road is experiencing an increasingly significant longitudinal slope, with an average of 3.3% and a maximum of 6%. These conditions pose severe safety risks, further heightened by the fact that most vehicles traveling on this road transport mineral resources, specifically large freight vehicles. As a result, traffic accidents frequently occur. The mentioned factors have caused trading obstacles between the Silk Road's middle and southern corridors. These hindrances impede the long-term economic and social development of Turpan City and the southern Xinjiang region.

3 Study on the selection of technical standards for the Shanku Highway

3.1 Principles for Selecting Technical Standards

3.1.1 Based on industry standards

The technical standards for the proposed project are chosen through a thorough analysis of its function and position within the regional highway network, together with factors such as existing traffic volume, terrain conditions, investment scale, environmental impacts, and other related projects. Furthermore, it is guided by the "Technical Standards for Highway Engineering" (JTG 01-2014) published by the Ministry of Transportation and Communications (MOTC), the "Specification for Highway Route Design" (JTG D20-2017), and relevant provisions from the Highway Capacity Manual (HCM2000), in addition to other pertinent specifications.

3.1.2 Full consideration of the realities of the situation

When formulating the standard, the proposed project underwent an analysis of the social environment. This analysis considered not only individual projects but also combined them with future national and local transportation planning, the direction of transportation development, and the demand for highway transportation in the context of social and economic development. The aim was to justify a flexible use of highway technical standards and determine the project scale reasonably.

3.2 Logical architecture for the selection of technical standards

For 20 years, highway technical standards have developed from basic theoretical research to systematic policy research.[2] With significant progress in highway construction in remote western regions, it is crucial to fully consider the unique characteristics of the new era of development orientation, high-quality transportation development orientation, road network architecture, investment returns, and more,[3] which will enable the construction of a logical framework in line with the actual development of the region for selecting technical standards that offer compelling solutions at the practical level. To offer sturdy backing for investigating practical solutions, the article suggests hierarchically constructing the primary influential factors based on the three dimensions of demand, decision-making, and conditions.

3.2.1 Demand-oriented

The construction of highways has both public welfare and profitability characteristics, requiring fast access and specific operating conditions. However, these goals can be contradictory, resulting in a need for an endogenous reciprocity power mechanism. To address this, technical standards for remote areas of the western region should consider regional functional positioning[4] and the formation of inter-regional co-development demand orientation, which should be prioritized in the construction of highways in this area.

The project is reliant on the connection between the G30 and G3012 lines. The G30 line, the Lianhuo Expressway, is integral to China's national highway network. Known as the "fourth horizontal" in the "five vertical and seven horizontal" system, it is the most critical highway in Xinjiang and plays a crucial role in connecting the province to mainland China. On the other hand, the G3012 line, also called the "Turpan - Hotan Expressway," connects four southern regions of Xinjiang. For a considerable period, the responsibility of connecting Xinjiang to the mainland provinces and assuming the role of a trunk highway has been in operation. The G3012 route, popularly known as the "Turpan-Hotan Expressway," serves as a crucial road network, linking the four southern border states and functioning as the primary skeleton of Xinjiang's highway network, mainly assuming the role of a trunk highway. The project's function is twofold: firstly, as a liaison between the G30 and G3012 lines, it optimizes the channel of the southern border out of Xinjiang; secondly, it develops a significant channel of resources in the hinterland of Turpan, promoting the development of local minerals and tourism resources.

3.2.2 Investment decision-making as a guide

Cost estimates in the early stages of project development are essential for making the right decisions, but they are a huge challenge and risk for owners and potential contractors due to limited information about the characteristics of a future highway project[5]. The "Golden Bridge and Silver Road" means that the highway project investment is enormous, and the highway investment during the construction period is often funded by the government budget funds as the medium, the financing platform as the carrier, with the support of the highway special fund for financing[6]; Highways construction projects are voracious of energy and material which outcomes a large amount of losses[7].for the vast western region, subject to limited financial resources, highway construction project investment has become an essential means of the inter-governmental game, to realize the overall local interests and the win-win situation of the regional interests along the routes.

Relying on the project traffic volume accounting, the near-term traffic volume in the study year is 7119PCU/day, the long-term traffic volume is 19061PCU/day, and the characteristic annual traffic volume statistics are shown in Table 1; according to the analysis of the investment measurement, the project is estimated to be more than 10 billion yuan, such as the use of the "government debt repayment road + enterprise implementation" mode[8], the capital financing using Enterprise capital + financial contribution + special debt funds + bank loan structure financing, following the requirements of the Development and Reform Commission, the capital ratio of 20% of the total investment in the project. After calculation, the toll revenue under this mode can repay the particular debt after maintaining the regular operation of the project but cannot repay the bank loan. Therefore, future project investment and financing modes are critical directions for highway investment consideration in remote areas in the West.

Table 1. Traffic Volume Forecast Results by Road Section

Unit: PCU/day

segmentation	Mileage (km)	2027	2030	2035	2040	2045	2050	2056
Kerbari Junction Interchange - Dikan Interchange	36.8	6902	8349	10539	12525	14471	16392	18520
Dikan Interchange - Nanshan Mining Area Interchange	79.7	7117	8593	10827	12864	14817	16801	19021
Nanshan Mine Interchange - Kumish North Interchange	53.15	7272	8766	11027	13143	15144	17187	19494
Weighted average of tolled sections	169.65	7119	8594	10827	12878	14845	16834	19061

3.2.3 grounded in reality

The fundamental conditions of highway construction include topography, environmental protection operation mode, etc. The topography impacts the structural approach adopted for constructing highways, the arrangement of structures, and the state of facilities along the route[9]. It is imperative to strictly adhere to environmental protection in highway construction[10]. Neglecting this red line cannot be tolerated. Additionally, the operation mode plays a significant role in generating and distributing traffic volume[11]; it necessitates specific standards for future infrastructures and public services.

The project is situated in the southern foothills of Tianshan Mountain. The terrain is generally high in the southwest and low in the northeast. The route traverses the Flaming Mountain Range via the pre-mountain alluvial floodplain inclined plains, then passes through the Kumutage Desert and low hill areas. The stratigraphic layers along the route comprise primarily the Devonian (D), Carboniferous (C), Permian (P), Jurassic (J), Cretaceous (K), Tertiary (N), and Quaternary (Q) systems, which are of utmost significance in the region. Designed for seismic protection in zone VII, the construction and maintenance costs of the highway in the remote western region are inevitably augmented by the intricate topography and geomorphology. For highway projects in remote western areas, the routes and construction should minimize damage to nature reserves' ecosystems. In road sections that cross experimental areas in nature reserves, establish biological corridors based on the migratory habits of animals or build bridges instead of roads to preserve connectivity and integrity of nature conservation ecosystems. The operation mode should consider both managing and maintaining this road section with convenience to reduce management and maintenance costs, as well as exploring socialization strategies in the operating market to increase the route's profitability.

4 Main technical indicators

4.1 Service level analysis

The level of service encompasses the quality of service that road users can expect to receive based on road conditions, traffic patterns, and the road environment. The provision of service can be objectively assessed by six indicators: (1) travel speed and duration, (2) vehicle maneuverability, (3) level of traffic obstruction, travel delays, and several stops per kilometer, (4) passenger safety, (5) traveling comfort and passenger satisfaction, and (6) cost-effectiveness. Each indicator is crucial for evaluating public The level of service V/C is typically quantified as the proportion of the maximum service traffic volume MSF_d to the base capacity C_p of the roadway, as determined by the equation (1)

$$V/C = MSF_d / (C_p \times N)$$

$$MSF_d = \frac{SF}{f_p \times f_{cw} \times f_{sw} \times f_N}$$

$$SF = DDHV / PHF_{15}$$

(1)

- SF -15-minute peak hour traffic volume in pcu/h;
- f_p, f_{cw}, f_{sw}, and f_N are correction factors representing the effects of the driver, travel lane width, left curb strip, and number of lanes, respectively, which can be selected through design criteria;
- $DDHV$ -O ne-way design hourly traffic volume in pcu/h;
- PHF_{15} -O ne-way design hourly traffic volume, take 0.863 according to the design standard;

Table 2 .Calculation of project level of service

sections	characteristic year	2027	2030	2035	2040	2045	2050	2056
Kelbari Interchange - Dikan Interchange	V/C	0.24	0.28	0.35	0.42	0.48	0.55	0.62
	service level	first-class	first-class	first-class	category B	category B	category B	three-tier
Dikan Interchange - Nanshan Mining Area Interchange	V/C	0.25	0.3	0.36	0.44	0.5	0.56	0.64
	service level	first-class	first-class	category B	category B	category B	three-tier	three-tier
Nanshan Mine Interchange - Kumish North Interchange	V/C	0.26	0.31	0.38	0.46	0.53	0.6	0.68
	service level	first-class	first-class	category B	category B	category B	three-tier	three-tier

Based on the previous formula and Table 2's design years, the project can maintain over three service levels during 30 years of operation. This suggests that the project's 120km / h speed and two-way four-lane design standard meet the service level requirements, which is also typical for western remote areas' service level evaluation model.

4.2 Structural form analysis

The structural form can be divided according to the Highway Engineering Technical Standards and Highway Engineering Design Standards. This paper will focus on the number of lanes and how to combine configuration analysis. To calculate the number of lanes, use the formula (2)

$$N = \frac{(AADT \times K \times D)}{(C_d \times f_{hv} \times f_n \times f_p)} \tag{2}$$

- $AADT$ -Annual average daily traffic in veh/h for the forecast year;
- K -Design hourly traffic volume coefficient: the project belongs to the western remote area, and according to the design standard, take 0.11;
- D -The directional inhomogeneity coefficient is 0.6 for this project.;
- C_d -The design capacity of each lane of the highway, which is taken as 1650 pcu/h/ln when the design speed is determined;
- f_{hv} -Correction factor for traffic composition on capacity, 0.85 according to design standards;
- f_n --Correction factor for the number of lanes, 0.97 according to design standards;
- f_p - the coefficient of overall driver characteristics, taken as 0.95 according to the design criteria;

According to the analysis of the service level mentioned above, Table 3 indicates the number of lanes required per direction for every characteristic year in the future. Each project section will require between 0.32 and 0.86 lanes 30 years after the road's opening. Therefore, using two lanes in each direction is sufficient to meet the traffic volume needs for this road section. The current design standards for operation conditions and service levels in remote areas in the West did not consider the adequate number of lanes required. To ensure smooth traffic flow, it is suggested that a minimum of four lanes in each direction be guaranteed for the arterial road network.

Table 3 .Number of lanes required for highway segments in a characteristic year

name (of a thing)	2027	2030	2035	2040	2045	2050	2056
Kerbari Junction Interchange -Dikan Interchange	0.32	0.38	0.48	0.57	0.66	0.74	0.84

Dikan Interchange -Nanshan Mining Area Interchange	0.34	0.4	0.49	0.59	0.68	0.76	0.86
Nanshan Mine Interchange -Kumish North Interchange	0.36	0.42	0.52	0.62	0.72	0.81	0.92

4.3 Analysis of construction options

In the construction project program, various sections of comparison and technical positioning standards must be addressed. This paper provides an example, outlining the primary factors that must be considered when demonstrating a construction program in remote areas of the West. Given the task of selecting the project's starting point, it is necessary to conduct a comprehensive analysis of the regional road network in Shanshan County. The project aims to connect the northern and eastern Xinjiang high-speed corridor G30 line to the north of Shanshan County, while the south of Shanshan County is adjacent to Kumutage Desert. Therefore, three possible choices for the project's starting point have emerged (Table 4).

- Option 1: Access is available near Qiketai on the east side of Shanshan County, with the starting point located on the east side of Lianmuqin Interchange and the west side of Shanshan West Interchange.
- Option 2: Access is between Shanshan County and Lianmuqin Township, with the starting point on the east side of Qiketai Township, which is connected to S241.
- Option 3: Access is available at Tuyugou, with the starting point on the east side of Tuyugou Township, to the east of Tuyugou Interchange, and approximately 4.5km from the G30 line.

Table 4. Comparative analysis of different construction options

programmatic	vintage	drawbacks
Option 1	1. Connected with highway net; 2. Near with local cargo source; 3. Close to the railroad station; 4. Connect with other economic points; 5. Near with travel source.	1. Large-scale tunnels and bridge structures; 2. High project cost and construction risk.
Option 2	1. Unconnected with highway net; 2. low cost per kilometer.	1. Far away from highway net;

Option 3	1. Connected with highway net;	1. Construction hard; 2. Steep terrain and vertical indexes; 3. High project cost and construction risk.

The construction program necessitates careful consideration of road network conditions, regional development, terrain, environmental requirements, heritage protection, project cost, and other relevant factors. Selection and measurement must be comprehensive. Due to the scarcity of resources in the three-gully corridor belt, this area is the central location for living and production. Unfortunately, prior occupation has caused negative impacts on local agriculture, water management, and transportation infrastructure, which has only been added to by the presence of sensitive environmental factors such as the Grand Canyon Scenic Area and Tuyugou Grottoes. Given these complications, implementing the proposed corridor program would unavoidably result in severe damage, leading local government and cultural relics protection departments to oppose this project. The second proposed starting point significantly increases construction mileage, with all routes passing through the sparsely inhabited Gobi area. While construction conditions are relatively simple, the routes bypass Shanshan County, an important economic hub along the proposed routes, thus offering little economic promotion and hindering the long-term development of the county. After conducting a comprehensive comparison, it is evident that the initial stages of Programs 2 and 3 possess significant drawbacks. Therefore, considering incorporating the factors mentioned above, it is imperative to emphasize the advancement of Program 1.

5 Conclusion

In summary, this article examines the selection of highway technical standards in remote western regions. It develops a logical framework for selecting these standards based on demand, decision-making, and foundation. Additionally, it highlights the primary technical indicators that must be considered in these remote areas and illustrates any differences with existing technical standards. The study's content offers information and guidance for highway construction projects in comparable regions.

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