Parameters and criteria the construction of the
Beijing expressway for urban planning

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Abstract. The purpose of the study is to investigate parameters and criteria the construction of the Beijing expressway for urban planning. The main methods of the study were statistical methods of studying the economic situation, analogy and generalization of the received information. Results. The assessment presented the method and scale of the construction of expressways, the method of construction of auxiliary roads, the method of designing entrance and exit ramps, research on the choice of overpasses for interchanges, as well as the impact of the construction of expressways on the entire urban transport environment. As part of the development of Beijing's transport infrastructure, it is necessary to coordinate the development of Beijing-Tianjin-Hebei transport. It continuing the reasonable construction of expressways. In this article, we presented main measures to improve the ring road that development of transport infrastructure in Beijing, Tianjin and Hebei, and active implementation of information systems in traffic management.

1 Introduction

At the beginning of the 20th century, with the growth of urbanization in Europe and the USA, developed rapidly automobile traffic, and urban expressways appeared. Many cities consider the system of urban expressways as framework of the urban road network, but the constant expansion of cities leads to the fact that the system of urban expressways cannot fully adapt to the development of urban traffic. Therefore, the design and transformation of the expressway system is of great importance.

Research and development of urban expressway design theory initially focused on the design of expressway systems, such as the design of high-speed ramps and overpasses, but now research is mainly focused on the coordination and control of expressways with urban spatial structures and urban external transport links.

Research on expressways in China has focused on the characteristics and design details, such as the study of the functions of expressways. In addition, some researchers pay attention to the analysis of the method and scale of the construction of expressways, the method of construction of auxiliary roads, the method of designing entrance and exit ramps, research on the choice of overpasses for interchanges, as well as the impact of the construction of expressways on the entire urban transport environment.

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2 Results

It is worth noting that the state actively participated in the development of Beijing's transport infrastructure. In the period 2016 to 2021, the length of expressways in Beijing continued to increase from 975 kilometers in 2016 and 1170 kilometers in 2021. As of the end of 2021, the length of highways in Beijing was 23,348.2 km, of which the length of expressways was 2,043.5 km. It was 20.2%, that more than last year. Figure 1 shows a graphical representation of the increase in the length of the Beijing Expressway.

![Fig. 1. The length of the Beijing Expressway from 2016 to 2021 (unit of measurement: kilometer).](image)

As of the end of 2021, the density of expressways in Beijing is 6.91 km per 100 square kilometers. Then we studied a more detailed description of the directions of these highways. We see that the highway located on the east from Beijing to Qianzi Street, Miyun County, Kuoshanji, Pinggu County and Xiji City, Tongxian County. It is located on the border Hebei Province and Tianjin City, as well as Haituo Mountain in Yanqing County, Lingshan Mountain in Mengtougou District and Hebei Province in the south. The mountainous area is located near the cities of Changouyi and Lixin in Daxing County, bordering Hebei Province. In the north, it is located border with Gubeikou in Miyun County, Shidongzi in Huaizhou County and Baihebao in Yanqing County and Hebei Province. Its width from east to west is about 160 kilometers, and its length from north to south – 176 kilometers.

During the "twelfth five-year plan" in Beijing, the average annual construction was 70 km. During the "thirteenth five-year plan", the average annual construction was 196 km. The construction tasks became more and more difficult. In the figure 2 shows diagram of completed, started and projected roads, according to data for 2022.
Beijing is carrying out preliminary work on the Jingxiong and the Changping expressway and a new expressway connecting the north-south of the airport. City authorities is making efforts to begin construction of a new national expressway. The Yanchong Expressway and the northern extension of Songliang Street were completed. According to data published by the Beijing Municipal Housing and Urban Development Commission, a total of 10 proposed expressway projects. Total construction length of more than 200 kilometers were registered in Beijing in 2021.

The Fifth Ring Expressway in Beijing is the first ring highway in Beijing. It is the dividing line between the urban area and the suburbs. It is the first large-scale infrastructure project. It was built as part of the 2008 Beijing Olympic Games project.

The Beijing Wuhuangcheng Expressway was launched on August 19, 2000 year. This highway was opened to traffic on November 1, 2003 year. The maintenance project was completed on July 16, 2015 year. Beijing's Wuhuangcheng Expressway has a total length of 98.58 km. The road is a two-way six-lane expressway with an estimated speed of 100 km/h. The total investment in the project amounted to 13.65 billion yuan.

In order to increase the capacity the Northeast City Corner Connecting Line, the airport Expressway was opened in the end at the end 2006. The airport connect the second Dongzhimen Ring Road and the third ring road of the Sanyuan Bridge. The ring roads significantly reduced the time from the city center in the capital. At the same time, Beijing's high-speed transport system was gradually being formed.

The Beijing Wuhuangcheng Expressway is located 10-15 km from the center of Beijing. It’s direction runs along the ring isolation strip between the urban area and the suburbs. The line passes through Chaoyang District, Haidian District, Shijingshan District, Fengtai
District and Daxing District, connecting 10 regional groups such as Beiyuan, Qinghe, Siyuan, Nanyuan, Yizhuang, Datou, Dingfuzhuang, Dongba, Jiuxianqiao and Wangjing. Key areas is located Olympic Facilities and Science City.

The urban street and road network within the central city is divided into four provincial levels according to the technical levels, according high-speed, trunk, secondary trunk and branches. Expressways develop urban transport. Beijing's urban expressway system consists of the so-called Second, Third, Fourth and Fifth Ring roads and 15 radial roads with a total length of about 380 kilometers. This system has no traffic lights and the main traffic hub in the city center. Its length is only 8% of the total length of the city's road network. It may carry more than 50% of the city's daily road transport in the future.

All the planned radii of the expressway were implemented by the end of 2005: Badaling Expressway, Jingkai Expressway, Jingjintang Expressway, Wanquanhe Street, Beijing-Shenyang Expressway, Lianhuachi West Road, Airport Expressway, Jingcheng Expressway and Xueyuan Road.

Two connecting lines of expressways were built in 2007. It is the North Tonghui Road, connecting the Second Ring Road of the Eastern Direction and the Jingtong Expressway and the road towards Fengbei, connecting the bridge of the Third Lize Transport Ring and the Jingshi Expressway. The other four express lines, Fushi Road, Puhuangyu Road, Xingshikou Road and Yaojiayuan Road, were launched one after the other. Figure 3 shows a diagram of the ring highway, which shows completed. At the stage of completion and projected highways.

Then we studied a more detailed description of the directions of these highways.

The Jingcheng Expressway starts from the Sun Palace Bridge on the Third Ring Road on the North through located the west side of Wangjing. The west side located on Shunyi Airport in Chengde. Inside the Fifth Transport Ring is the city Expressway. Outside the Fifth Transport Ring is the city expressway.

The airport expressway starts from the northeast corner of the Second Ring Road to the capital International Airport. It is a special expressway between the central city and the capital International Airport. The Yaojiayuan Road starts from the Changhong Bridge on the East Third Ring Road. East located the Dongba Edge Group leading to Pinggu New Town (connected to the Jingping Expressway).

Tonghui North Road and Jingtong Expressway start of the Second Ring Road in the west. The south side, located in the Central Business District (CBD), Dingfuzhuang Edge Group, Tongzhou New City to Shanhaiguan (connected to National Highway 102).

The Beijing-Shenzhen Expressway starts from the Xi Fang Bridge on the Eastern Fourth Transport Ring in the west and goes east through Tongzhou to Shenyang. An urban expressway runs within the Fifth Transport Ring, and an expressway runs outside the Fifth Transport Ring.

The Beijing-Tianjin-Tanggu Expressway starts from the southeast corner of the Second Ring Road and leads to Tianjin and Tanggu via the Maju and Yongle Bridge. The inner part of the Fifth Ring Road is an urban expressway, and the outer part of the Fifth Ring Road is an expressway.

The southern continuation of Puhuangyu Road starts from the Yuting Bridge on the Second Ring Road and goes south through the Fangzhuang district and the Nanyuan Extreme Group to Jinan (connects with national roads 104 and 105).

The Jingkai Expressway starts from the Caihuin Bridge on the Southwest Second Ring Road and goes south through the New City of Daxing to Kaifeng. An urban expressway runs inside the Fifth Ring Road, and an expressway runs outside the Fifth Ring Road.

Fengtai Road starts from Caihuying Bridge on the Southwest Second Ring Road and located west through Fengtai Edge Group is connected to Beijing-Shijiazhuang Expressway and leads to Shijiazhuang.
The eastern Lianhuachi Road and its western extension line start from the Shining Temple Bridge on the second Western Ring Road in the east and go west through the Shijingshan Yamen Gate in the direction of Yuanping, Shanxi (connected to National Highway 108).

Fushi Road starts from the Aerospace Bridge on the western Third Ring Road and goes west through Shijingshan and Mentou to Datong (connects to national Highway 109).

The Wanquan River starts from the Suzhou Bridge on the western Third Ring Road and flows north through the western side of Yuanmingyuan to the Zhongguancun Science and Technology Park Development Zone behind Haidian Mountain.

The Badaling Expressway runs from Deshengmen to Zhangjiakou through Qinghe Edge Group, Huilongguan District, Changping and Yanqing New City. An urban expressway runs within the Fifth Transport Ring, and an expressway runs outside the Fifth Transport Ring.

As of the end of 2021, the density of expressways in Beijing is 6.91 km per 100 square kilometers. This is the third place in the country. During the "twelfth five-year plan" in Beijing, an average of 70 km were built annually [16]. During the "thirteenth five-year plan", the average annual construction was 196 km. The construction tasks became more and more difficult. Key planning of the ring expressway of the metropolitan region (Tongzhou-Daxin section). The Beijing-Qingdao Expressway (Beijing section) has been completed and opened to traffic. The last two high-speed roads between Beijing, Tianjin and Hebei have been improved [16].

Due to the rapid development of Beijing, the original scheme was not adapted to the development of the city. The creation of the first ring road as an expressway around the city has not been implemented. Therefore, the task was to optimize the road infrastructure. To do this, it was decided to build ring roads, which made it possible to relieve the increasing traffic flow [17].

To date, Beijing already has six ring roads inside the city, the public calls the new expressway between Hebei-Tianjin-Zhangjiakou the "7th Ring Road". However, only 38 km of the expressway passes through Beijing, another 38 km - through Tianjin, and the remaining 924 km - through Hebei. Figure 2 shows a diagram of the 7th ring road [15]. In the figure 3 shows schematic diagram of the seventh ring road.

**Fig. 3.** Schematic diagram of the seventh ring road.
The expressway looks like a huge necklace connecting 13 major cities around Beijing, including Chengdu, Lanfang, Guan and Chunli, which will improve the transport network of the Beijing-Tianjin-Hebei area [12].

According to some experts, if the second ring road is completely connected to it, it will lead to the fact that some transit vehicles will arrive in the central district of Beijing and will use the second ring road unnecessarily [12]. For example, trucks from the Beijing-Tianjin-Tangshan expressway will go to the Badala high-speed ring road, the distance is less, but this will inevitably lead to an increase in the number of cars on the second ring road and, accordingly, a high load on the roadway [13].

Therefore, when implementing the Beijing ring road expansion project, it is necessary to use innovative technologies. Consider the technologies that were previously used on five expressways adjacent to Beijing:

1. Hongshankou Viaduct crosses Jinmi Aqueduct diagonally. Its total length is 213 m. [14]. It uses four-span prestressed concrete solid beams. After repeated analysis and comparison, a new design concept was adopted - depreciation combined with earthquake resistance. The shock-absorbing support of a hyperbolic bridge with a restriction function, the elastic rigidity of the support is provided by a plate spring [26]. Thanks to the installation of a shock-absorbing bearing to adjust the overall stiffness of the support column, the seismic reaction of the bridge is significantly reduced, and at the same time a restrictive device is installed. A certain relative displacement between the upper and lower parts of the bridge makes it possible to adapt to changes in displacement during normal operation, which meets the requirements for the bridge voltage under various operating conditions, optimizes the stress state of the pier and column and saves investment in substructure [16].

2. Introduction of foreign modeling technology in combination with traffic volume forecasting. At the same time, the simulation of traffic on the forms of interchanges is evaluated. The installation standards and the scale of junctions of the nodal type are suitable for the entire line. High-class directional ramps are used throughout the line, which makes it possible to eliminate the interchange zone on the highway [28]. Ramps have increased the capacity of interchanges and the level of service of the system in the main directions of intersections. The purpose of balancing is the flow of the road network and ensuring the consistency of the service level [9].

3. The innovative technology of verifiable pre-tension of the bridge is used in steel-reinforced concrete combined beams of the Jingshan railway viaduct. This solves the problem of the impossibility of maintaining the pre-voltage. Replacing the problem increased the safety and durability of the bridge [7].

4. In China, there were no technical conditions for the processing of construction slag and construction experience. The technology of processing the basis of construction slag was worked out. Local experts have organized research on the Fuxi Road overpass. In the area of the Fifth Transport Ring, the feasibility of a technical scheme for processing the base of construction waste was investigated and demonstrated. For the first time, complex processing technologies, such as dynamic compaction and expansion of piles, DDC piles and blue pie impact compaction, were used to eliminate areas of poor foundation filling, for example, artificial filling with construction debris from 15 to 30 meters deep, and tracking and monitoring was also carried out [8]. Insulating piles are installed in the middle supports of the bridge, and the method of compaction of gravel piles is used behind the supports to strengthen the embankment. The soil resistance of the embankment was increased around the piles. After the tests, there is no draft of the bridge supports and abutments, and the total draft of the treated road section is less than 2 cm, which meets the requirements of the design documentation. The event allowed to save the cost of the project. This is the accumulation of valuable experience for future construction waste.
5. The viaduct of Shijingshan South Station of the second stage of the Beijing Expressway of the Five Ring Cities is the first cable-stayed bridge in Beijing. Special ramps were used in the project, which are fixed lanes designed for turning on the overpass [12]. Ramps have a large radius, and vehicles can make the most of it when turning. The speed of the car is usually from 60 to 80 kilometers per hour, and the total speed of the exit is only 30 kilometers per hour. Three directional exits connect the traffic flow from the west to the north of the city, which solves big problems [3].

As part of the development of Beijing's transport infrastructure, it is necessary to coordinate the development of Beijing-Tianjin-Hebei transport. It continuing the reasonable construction of expressways. The main measures to improve the ring road are presented in table 1.

Table 1. Measures to improve the Beijing Ring Road.

<table>
<thead>
<tr>
<th>Direction of development</th>
<th>Basic measures</th>
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<tbody>
<tr>
<td>Development of transport infrastructure in Beijing, Tianjin and Hebei</td>
<td>1) Optimize urban transport links between the two airports, complete the project of high-speed expansion of the northern line of the new airport from east to west and promote the development of the new airport. Construction of the check-in function at the Ze City terminal and Dongzhimen Airlines on the line of the capital airport; 2) Improve the expressway network, promote projects such as the Chengping Expressway, and further strengthen the interconnection between Beijing, Tianjin and Hebei. 3) Accelerate the transformation of the Eastern Sixth Ring Road and the migration of the functions of national highways outside the country, as well as promote access roads and other roads. Construction of a road network, construction of a rapid transit demonstration corridor along the Guangqu Road and the implementation of the 41-kilometer Beijing section of the Grand Canal. Navigation on linear cruise ships; 4) Transportation in the new Xiongan district will be more convenient. Accelerate the construction of the Jingxiong Expressway and work together to promote the new Xiong'an. Construction of an express line (line R1) from the district to Beijing Daxing International Airport to implement an accelerated route between Beijing and Xiongan New District.</td>
</tr>
<tr>
<td>Active implementation of information systems in traffic management</td>
<td>1) Build the third phase of the Traffic Monitoring and Dispatching Center (TOCK) to achieve integrated traffic management and coordination. Functions such as planning, emergency response and decision support; 2) Completed the joint demonstration project of the Beijing section of the Yancheng Expressway and announced the construction of an intelligent expressway. 3) Intelligent transformation of the city traffic light system to implement intelligent adjustment of important signal lights in the entire road network</td>
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3 Conclusion

The presented solutions will solve the key problems. Basically, the transport framework of the city's subcenter will be formed, where public transport services will be significantly improved. It is necessary to implement a high-speed highway between the city and the new Songshan district in Hebei Province. The integration of Beijing-Tianjin-Hebei transport will
be accelerated, as well as the accelerated economic and social development of the southern part of the city

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