Research on Location Model and Scale Parameters of Multi-functional Expressway Service Area

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Abstract. In order to improve the scientific, rationality and characteristics of the construction of expressway service area, the main points of planning and layout of service area were studied. Firstly, the requirements and concepts of highway location selection under different functional orientations are qualitatively analyzed. Secondly, the location model is quantitatively studied based on statistics and operations research. Finally, based on the needs of people and vehicles, the scale parameters of the service area were revised. The research results show that the design concept of the service area should be targeted. The service area of different location models have different emphasis. The scale parameters of the service area should be adjusted according to the needs of people and vehicles.

1. Introduction
The service area is an important part of the expressway and plays an irreplaceable role in the traffic safety of vehicles and the rest services of drivers and passengers. Due to the limitations of research methods and the differences of regional development, the overall pattern of service area lacks individuality and pertinence, which leads to low social service capacity [1]. Especially in recent years, the introduction of open service area and new service area has challenged the applicability of traditional service area. It is urgent to find a new service area layout method with distinctive features. Therefore, in order to promote the scientific and rational construction of the service area, and to develop the logistics warehousing and regional characteristics of the service area, this paper analyzes the layout points and scale parameters of the expressway service area [2].

2. function positioning

2.1. Business travel
Through the mobilization of surrounding resources in all directions, scientific and rational use of humanities and regional culture, the service area itself has become a tourist attraction.

2.1.1. overall arrangement. The layout of the tourism-type service area is more suitable for centralized use, and the centralized type can avoid the phenomenon that the resource-side entry rate is higher due to the asymmetric distribution of tourism resources. At the same time, it conforms to the trend of layout [3].
2.1.2. Landscape order. The humanistic landscape of the tourism-oriented service area should not be contagious and ornamental, instead of carrying out under the guidance of mainstream society and culture. Only the constrained and rationally applied landscape elements can make the multidimensional mechanism be spiritual, material and social [4].

2.1.3. Basic needs. When the infrastructure of the service area is sufficiently sophisticated, other functions derived from it will be activated. If the basic physiological needs of the driver and passenger are not met, the overall service level and efficiency of the service area will be greatly reduced. All in all, the characteristics of the tourism-type service area need to be based on high-quality basic settings, and cannot be reversed.

2.2. Passenger transportation

2.2.1. Delivery mode. There are three types of mainstream distribution modes in China: the third-party logistics distribution mode, the enterprise self-operated distribution mode, and the different modes of the common distribution mode. The characteristics should be different according to the specific service area.

2.2.2. Information network. The efficiency and accuracy of logistics transportation depend on Tongda's distribution information network. The perfect communication system of the expressway itself provides a good information platform for the logistics operation of the service area. Therefore, the logistics-type service area can fully utilize the integrated information system of the expressway network while constructing the information network, and further improve the timeliness of distribution while realizing the logistics network of the service area [5].

![Image](image_url)

Figure 1. Information network composition module diagram.

2.2.3. Passenger flow transit. In addition to the transportation of “things”, the logistics service area can also carry out “guest” transportation. The passenger flow service area can establish a passenger station in the area or next to the area. This station can be used for long-distance buses or city bus stops. A dynamic electronic display can be set up at the parking spot to provide passengers with dynamic real-time information. The passenger flow function of the service area not only alleviates the congestion caused by urban transportation problems, but also creates economic benefits for itself.

3. Location layout model
The location-based layout model based on mathematics and operations research provides a quantitative analysis of the planning of the service area. Commonly used location models include: passenger flow determination method, center of gravity method, shortest path method. Commonly used location models include: passenger flow determination method, center of gravity method, shortest path method.
3.1. Shortest path method
The shortest path method is to determine the position of the hub by studying the OD pair between the alternate hub points or the number of shortest and short circuits between the nodes of the bus network. The shortest path method is used to select the location of the service area[6]. The specific formula is as follows.

\[
G = \max \{W_\alpha / W_j\} \; (\alpha = 1, 2, \ldots, P)
\]

\[
A_i = E_i / 2n(n - 1)
\]

\[
E_i = \sum_{j,k \in Q} \delta_{jk} E_{jk}^i
\]

\[
W_j = 1/2 \sum_i x_{ij}, \; (1 \leq j \leq N)
\]

\[
G: \text{the selected set of planned bus hubs; } A_i: \text{the inclusion coefficient of OD point or node } i. \; A: \text{the OD point or the selection coefficient of the bus hub node. } E_i: \text{the shortest route and the next time through the alternative hub. } N: \text{the OD point or node set. } n: \text{the number of nodes.}
\]

The location obtained by the shortest path method is located in the process of interaction between points, and is the node with the most frequent passages, which can ensure the surrounding traffic and road strips to a certain extent. However, the shortest path method also has certain shortcomings, and it is easy to fall into the local optimal solution.

3.2. Passenger flow decision method site selection
The passenger flow decision method is divided into two categories: passenger flow distribution location method and passenger flow location method model. The specific model is as follows:

\[
W_j = 1/2 \sum_i x_{ij}, \; (1 \leq j \leq N)
\]

\[
G = \max \{W_\alpha / W_j\} \; (\alpha = 1, 2, \ldots, P)
\]

\[
W_j: \text{the passenger flow of each traffic cell and bus hub. } d_j: \text{the linear distance between each traffic cell and bus hub. } r_j: \text{the time required to reach the average rate of each other.}
\]

In the plane of gravity, the gravity model considers each cell that generates traffic flow as an average distribution system, and takes the amount of travel and the amount of attraction as the weight of the object, so that the center of the entire system can be used as the optimal set point. It is the primary address of the hub.

3.3. Center of gravity
The center of gravity method is to select the site, that is, to select the site by gravity model. The steps are as follows: n nodes are set, the coordinates are set to (xi, yj) (j = 1, 2, ... n), and the coordinates of the bus hub are set to (x0, y0). Then the best location points x* and y* are.

\[
x^* = \frac{\sum_{j=1}^{n} r_{ij} w_j x_j d_j}{\sum_{j=1}^{n} r_{ij} w_j d_j}, \; y^* = \frac{\sum_{j=1}^{n} r_{ij} w_j y_j d_j}{\sum_{j=1}^{n} r_{ij} w_j d_j}
\]

4. Scale parameter
The size of the service area should not be simply positioned at the basic service level. It is necessary to
broaden its functions and fully consider the future development trend.

4.1. Spacing setting
The distance between foreign service areas is usually 16-100km, and in China, it is usually 30-100km. It can be seen that the installation interval of the service area is still wide and the difference is large. Therefore, in the planning and design, reasonable spacing should be selected according to the actual situation along the line[7]. For this reason, the distribution of some expressway service areas in China is counted as a reference.

Table 1. The layout of service facilities along the highway in China.

| highway            | Full length (km) | Rest facility  | Average interval | Number of service areas |
|--------------------|------------------|----------------|------------------|-------------------------|
| Jingjintang Expressway | 155              | SA             | 50               | 3                       |
| Jiqing Expressway  | 317              | SA(Massive)    | 60               | 4                       |
| Shenda Expressway  | 378              | PA             | 40               | 3                       |
| Beijing-Shenyang Expressway | 360          | SA             | 50               | 6                       |
|                    |                  | PA             | 30               | 6                       |

First consider the needs of people and vehicles. The driver's good state is maintained for 1 to 1.5 hours, and the corresponding driving distance is 60 to 150 km. Secondly, the average person's toilet time is between 2 and 3 hours, and the corresponding distance is 120 to 300 km. In addition, the car itself has a fuel limit. Under normal circumstances, the vehicle is red-lighted from the fuel meter and the fuel is exhausted. It is 30 to 50km. In summary, the service area spacing should be set between 30 and 50 km. Finally, social factors such as medical assistance, fire prevention and disaster relief, etc., can also be considered.

4.2. Driving rate
The determination of the driving rate of the service area is the premise of planning and designing, which directly determines the construction scale and operational effect of the service area. At present, the domestic common reference driving rate is shown in the following table.

Table 2. Driving rate of different types of vehicles.

| Type of facility | Vehicle type  | Vehicle Entry Rate |
|------------------|---------------|--------------------|
| Service area     | Small car     | 0.175              |
|                  | Large bus     | 0.25               |
|                  | Large truck   | 0.125              |
| parking lot      | Small car     | 0.1                |
|                  | Large bus     | 0.125              |
|                  | Large truck   | 0.1                |

However, the reference driving rate is mostly empirical, and with the increase of traffic volume in recent years, it is not fully applicable to the actual situation. To this end, based on the physiological needs of human beings, a new service area driving rate model is constructed based on the condition that a continuous driving of 2.5-3 hours must be taken to the service area.

\[ T = \frac{KA}{V}, t \in (2.5 - 3) \] (4)

T: the driving rate. K: the coefficient. t: the driving time. A: the average spacing of the service area. V: the average speed of different types of vehicles. The statistical data is used to verify it. The results show that the driving rate model has a higher fitting rate with the actual service area.

4.3. Parking area
The size of the parking lot determines the size of the service area. The size of the parking area is determined by the number of parking spaces and the average parking space. However, modern
highway engineering research theory has not yet established scientific mathematical models and formulas for it. To this end, this paper counts the area of some parking lots in China and the total area of service areas, as shown in the following table.

Table 3. Parking lot area and total land area.

| Service areas | Wuhan | Chongqing | Guiyang | Yibin | Yancheng | Yichang |
|---------------|-------|-----------|---------|-------|----------|---------|
| Total land area | 73368 | 53334 | 93857 | 87156 | 60036 | 68156 |
| Parking lot area | 17945 | 12356 | 19023 | 15656 | 15623 | 16167 |

It can be seen from Table 3 that the parking lot area in China is between 10,000 and 20,000, the service area is between 5,000 and 10,000, and the parking lot is between 20% and 30%. It is calculated by mathematical statistics. In order to obtain an index relationship between the parking lot area and the floor space, as shown in the following formula.

$$ S = 13901e^{3E-0.6x} $$  \hspace{1cm} (5)

S: total parking area. x: total area of service area.

4.4. Turnover rate and peak rate

The peak rate of the highway has nothing to do with the type of vehicle. The turnover rate of different types of vehicles is quite different [8]. For example, the small car is only need simple service such as refueling, rest, and the parking time is very short; the bus parking time is relatively fixed and tight; For the truck, it takes time for the driver to recover from long-distance driving fatigue and the longest parking time. So this paper has revised the turnover rate and peak rate of different vehicles through field investigations, as shown in the following table.

Table 4. Different models turnover rate and peak rate.

| Vehicle type | Parking time | Peak rate | Turnover rate |
|--------------|--------------|-----------|---------------|
| Truck        | 100          | 0.10      | 0.47          |
| Bus          | 30           | 0.12      | 2.8           |
| Car          | 25           | 0.11      | 2.21          |

5. Conclusion

The layout and scale design of service area should be scientific, rational and characteristic. On the premise of saving land resources and improving the resource allocation of facilities in the service area, the facilities in the service area are guaranteed to be suitable for the traffic flow of services, to maximize the functions of the service area, and ultimately to improve the service level of expressway.

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