Research on Optimization Design of Conventional Bus Station

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Abstract. In the public transportation system, bus stops are important nodes connecting bus vehicles and passengers, as well as an important link to achieve efficient boarding and alighting and to ensure that the public transportation system operates properly. Therefore, the setting of bus stops is very important. Unreasonable platform design will lead to problems such as chaotic bus stops, which will lead to traffic bottlenecks near bus stops. In order to improve this phenomenon, the number of berths and the type of platform can be properly planned. This paper considers the influencing factors that affect the selection of linear platform and harbor platform, and puts forward the process of platform form selection. The parking service process of the bus is regarded as a queuing process, and the method of determining the number of berths is given by using the queuing theory.

Keywords: bus station, number of berths, queuing theory, design optimization, selection

1 INTRODUCTION

In the process of urbanization in China, the level of people' s travel has been greatly improved and the number of motor vehicles has continued to increase. These factors have caused serious traffic congestion and an increasingly acute contradiction between the supply of roads and people 's travel needs. The development of public transportation has become one of the effective measures to alleviate this contradiction. At the same time, it is also an inevitable trend to meet people 's travel needs, promote sustainable social development and improve travel modes. In order to improve the operation ability of the conventional bus stop, the platform can be optimized. This paper gives two solutions of linear and harbor type from the factors that affect the form selection of the platform. When the bus stops at the platform, its service process can be regarded as a queuing process. Based on the queuing theory, the number of berths on the platform is optimized.

Sekhar, S. P. and Arpan M. [1] analyzed the acceleration and deceleration characteristics of different vehicles at roadside bus stops. During the bus stop, the speed-distance curve of each bus station type vehicle is drawn, and the linear and nonlinear regression analysis of each vehicle is carried out. The research results provide a reference for the

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geometric design of the bus station and help to understand the phenomenon of traffic flow interruption when there are vehicles parked on the linear platform. Sravya, L. J, Raunak M, et al.[2] used the data obtained from CATS to study the relationship between bus reliability and the number of passengers on the bus station. The reliability of the platform bus was obtained by calculating the punctuality rate of the bus, and the data of the number of passengers obtained from the survey were processed to obtain the relationship between the reliability rate of the bus and the number of passengers, so as to improve the operation efficiency of the bus. Wang WJ [3] used VISSIM simulation software to build a simulation model of the target bus station. The simulation results of the target bus stop capacity were obtained through simulation, and compared with the calculation results of the theoretical model to verify the saturation. The effectiveness of the bus stop capacity model. Secondly, the target station is transformed into a tandem double-harbor and a parallel double-harbor bus station. The simulation results are compared with the theoretical model calculation results to verify the effectiveness of the unsaturated state bus stop capacity model. Finally, the parking capacity of the bus station and the optimization efficiency of the bus delay in the two reconstruction schemes are compared and analyzed. It is concluded that the transformation of the target station into a tandem double bay bus station can more effectively improve the parking capacity of the bus station and better meet the needs of the target station. Chen L [4] uses the traffic flow cellular automata model to simulate the road traffic flow near the bus stop, and explores the impact of the bus stop set near the signalized intersection on the traffic efficiency of the intersection. By using the existing traffic resources to solve the problem of traffic congestion, it is not only beneficial to improve the traffic capacity of the road section near the bus stop, but also to improve the traffic condition near the intersection, which is of great significance to solve the urban traffic problem.

2 SELECTION OF BUS STATION FORM

The bus station can be divided into linear platform and harbor platform according to the form of the station. The former is the most common form, and the vehicle parking space is usually set to the outermost motorway. The characteristic of the bay-type platform is to widen the road section around the bus platform to the outside part (generally 3m), and establish a bus platform outside the normal lane. The purpose is to reduce the occupation of the lane when the bus is parked as much as possible, mainly considering reducing the impact of bus parking on road capacity. The parking process of the bus is roughly divided into opening the door, getting on and off, and closing the door. If the bus is parked at the linear platform, the road near the platform is easy to form a traffic bottleneck. At this time, public transport vehicles and social traffic also face two choices, one is to slow down and wait, and the other is to change lanes. In the accelerated departure stage of the bus, for the linear platform, it is manifested as a bus accelerating from zero speed to normal following state. If it is a harbor platform, then the vehicle needs to change lanes. When the traffic flow density on the road section near the platform is large, the acceleration or lane change behavior of the bus will cause interference to the social vehicle.

2.1 Influencing Factors of Platform form Selection

Number of Lanes. In the case of fewer lanes, especially on single-lane roads, linear bus stops are usually a more common choice. This design allows buses to stop without leaving the lane, reducing interference with traffic flow. Because there is no special parking area, it may affect the passing vehicles. However, if conditions permit, you can also consider setting a harbor-type platform to reduce the impact of bus stops on road traffic. When the number of lanes is large, the traffic flow is large, and the harbor platform provides a parking area for the bus by partially widening the road surface, thereby avoiding the occupation of the lane when the bus is parked and reducing the impact on road traffic.

Construction Cost. Its requirements for the selection of the platform are roughly simpler than the linear platform. The construction difficulty of the straight-line platform is relatively low. It is usually only necessary to set up waiting kiosks, station boards and other facilities on the side of the road, and there is no need to carry out large-scale transformation of the road. Therefore, the construction investment is also lower than that of the bay-type platform. In addition, we must also consider its comprehensive benefits and long-term planning. Although the construction cost of the harbor platform is higher, its comprehensive benefits in improving the efficiency of bus operation and enhancing the image of the city are more obvious. Therefore, in urban planning and construction, the type of bus station should be reasonably selected according to the actual situation and long-term planning objectives, so as to achieve the best comprehensive benefits.

Road Traffic Volume. When the traffic volume near the platform is relatively low, the linear stop station is usually selected due to the cost problem. The influence of the linear platform on the road traffic is relatively limited, and the bus stop will not occupy more lane space and lead to traffic congestion. On the road section with large traffic volume, if the linear platform is selected at this time, it may form a traffic bottleneck, because the bus stop will occupy the lane, resulting in other vehicles needing to slow down or detour, thus affecting the overall traffic capacity of the road. The bay platform provides a special parking area for the bus by locally widening the road surface. This design allows the bus to stop without occupying the lane space, thereby reducing the impact on road traffic.

2.2 Station form Selection Process

Field Investigation. First of all, it is necessary to clarify the purpose of this survey in order to optimize the layout of existing bus stations and improve traffic efficiency. Then traffic flow observation, road condition assessment, passenger demand survey and other processes are carried out. The traffic flow of the survey section was observed and recorded at different time periods, including the flow of motor vehicles, non-motor vehicles and pedestrians, and the parking frequency, parking time and queuing of buses were collected. The road width, number of lanes, road conditions and other conditions of the reconstructed road section are evaluated, and it is noted whether there is enough space for the expansion of the bus station. At the same time, it is also necessary to investigate the surrounding environment of the platform, including the nature of the land around the platform, the layout of the building, pedestrian activities, etc., and consider whether the setting of the bus station will cause inconvenience to the surrounding residents and merchants.

Determine the form. When choosing the form of the platform, you can choose to minimize the delay time of the bus, or you can choose to minimize the delay time of the passengers, do a good job of layout convergence, and formulate feasible plans according to local conditions under the permitting conditions of the site. From two angles and based on the survey data of the first step, you can choose a linear platform or a harbor platform. From the perspective of vehicle delay, the linear platform reduces the delay of the bus itself due to the convenience of parking when the traffic flow is small. However, with the increase of traffic flow, it has a significant impact on the delay of social vehicles, which is easy to lead to traffic congestion. The bay-type bus stop effectively reduces the impact of bus stops on social vehicles by providing an independent stop area. Although the bus in and out of the bay area may bring some delays, it generally helps to reduce the delay of the entire transportation system. From the perspective of human delay, the advantages of the harbor platform are more obvious. It not only provides passengers with a safe waiting environment and reduces the waiting anxiety caused by frequent bus stops, but also improves the waiting experience of passengers by equipping them with seat facilities. Although the waiting time of passengers during peak hours may still be affected by factors such as bus full load rate, the bay platform has more advantages in improving passenger satisfaction than the linear platform.

3 DETERMINATION OF THE NUMBER OF BERTHS AT THE BUS STATION

3.1 Optimization of the Number of Bus Station Berths

The queuing theory is used to calculate the number of berths: on the platform, the arrival of the bus can be regarded as a Poisson distribution, and the parking time can be approximately subject to the Erlang distribution. When the bus stops at the platform, its service process can be regarded as a queuing process. According to the idea of queuing theory, the number of berths required can be determined[5].

3.2 Determination of the Number of Platform Berths

When there is no bus priority measure, the arrival of the bus can be regarded as a Poisson distribution, and the vehicle stop service time can be regarded as an Erlang distribution. However, due to its lack of memory, it is difficult to analyze. It is necessary to divide it into multiple exponential distributions to obtain a multi-stage model.

Therefore, the service channel of the bus station can be regarded as an ' M / M / N queuing service system '. The queuing system is shown in Figure 1.

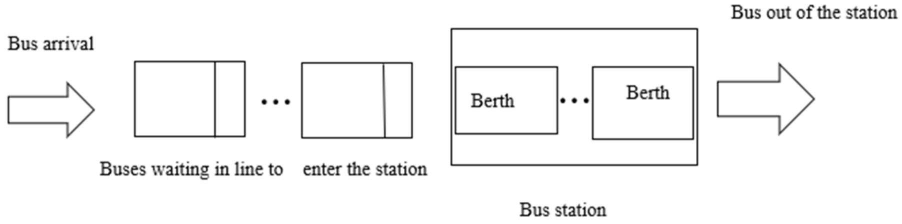

Fig. 1. M / M / N queuing service system.

3.3 Berth Number Calculation Process

Probability of no bus stop at the platform[5]:

$$P_{(0)} = \frac{1}{\sum_{0}^{N-1} \frac{\rho^k}{k!} + \frac{\rho^N}{N!(1-\rho/N)}} \tag{1}$$

The probability of k vehicles entering the station at the platform:

$$P_{(k)} = \frac{\rho^k}{k!} P(0) \quad k < N \tag{2}$$

$$P_{(k)} = \frac{\rho^N}{N!N^{k-N}} P_{(0)} \quad \mathrm{k} \geq N \tag{3}$$

The average number of vehicles in the platform service system:

$$\bar{n} = \rho + \frac{\rho^{N+1}}{N!N} \cdot \frac{P_{(0)}}{(1-\frac{\rho}{N})^2} \tag{4}$$

In the formula: N——bus berths;
λ——Bus arrival rate;
μ——service rate;
ρ——service intensity, $\rho = \lambda / \mu$, When $\rho / N < 1$, the queue is stable; when $\rho / N \geq 1$, the queue is unstable; that is, the queuing system is in a normal state when $\rho / N < 1,\ N > \lambda / \mu$. The λ here represents the sum of all bus departure frequencies obtained from the survey. The value of μ is obtained by the sum of the average parking time of the vehicle on the platform and the minimum headway of the two adjacent

vehicles. The process of calculating the reasonable number of berths on the platform is: first step, the ρ value is calculated according to λ and μ, and the appropriate initial berth number N0 is determined, which satisfies $\rho / N < 1$. the second step, when there are N0 berths, the average number of buses $\overline{n_i}$ in the platform is determined according to the above process; third step, determine whether $\overline{n_i}$ satisfies $\overline{n_i} \le N_{ie}$ and $P(k > N) < \theta$

N_{ie} —— Number of validated berths available at station N_i parking spaces, See Table 1.

θ ——The probability of a bus entering the platform queuing system is usually 5 % to 10 %.

If $\overline{n_i}$ conforms to the above formula, the iteration is ended, and the platform is set according to the number of N_i berths; If $\overline{n_i}$ does not conform to N_i, let $N_{i+1} = N_i + 1$, return to process the second step, and recalculate according to the original process.

Table 1. Table of Effective Berths.

Sequence number of station arrangement	Linear platform		Harbor-shaped bus stop	
	Utilization efficiency (%)	Cumulative effective station	Utilization efficiency (%)	Cumulative effective station
1	100	1	100	1
2	85	1.85	85	1.85
3	60	2.45	75	2.6
4	20	2.65	65	3.25
5	5	2.70	50	3.75

3.4 Case Application

Taking Jiaozuo Maternal and Child Health Hospital Station as an example, assuming that the bus arrival rate of the station is 74veh/ h, the average service time of the vehicle is 19.4s, and the average headway is 9.6s. According to the previous queuing theory method, the number of berths on the platform is solved:

$$\lambda = 74veh / h,\ \mu = 3600/(19.4+9.6) = 124.1,\ \rho = \frac{\lambda}{\mu} = \frac{74}{124.1} = 0.59.$$

Let $N_0 = 2$, then $P_{(0)} = 0.52,\ \overline{n_0} = 0.65$. Combined with table 1 of effective berths, it can be calculated that: $N_{0e} = 1.85$, $\overline{n_0} \le N_{0e}$, $P_{(1)} = 0.3186$, $P_{(2)} = 0.094$, $P(k > N) = 0.028$

Therefore, the calculated number of 2 berths is to meet the requirements. Has met the requirements do not need to continue to calculate. In summary, two berths are used as the vehicle design stations of the platform.

4 CONCLUSION

The bus station is an important node connecting buses and passengers. Unreasonable platform design will lead to traffic bottlenecks near the platform. This paper focuses on the form selection and berth number design of the bus station to optimize the design of the platform. Specifically, choose a linear platform or a harbor platform based on the minimum delay of buses or people. The arrival of the bus is regarded as a Poisson distribution, and the service channel of the bus station is regarded as an ' M / M / N queuing service system '. The reasonable number of berths on the bus station is obtained by using the queuing theory. The optimization design of bus station platform can effectively improve the operation efficiency of bus vehicles and the traffic capacity of main roads, and help to improve the urban road traffic environment.

REFERENCE

1. Sekhar, S. P., Arpan M., "Longitudinal Acceleration and Deceleration Behavior of Vehicles at the Curbside Bus Stop Under Mixed Traffic Conditions, " Journal of The Institution of Engineers (India): Series A, 2023, 104(3): 615-632.
2. Sravya, L. J, Raunak M, et al., "Examining the association between bus transit reliability and the number of boarding passengers, " Public Transport, 2023, 15(3): 675-696.
3. Wang WJ., "Study on the capacity of bus stops in Hong Kong," Chongqing Jiaotong University, 2023.
4. Chen L., "Research on the influence of linear bus stop on intersection traffic efficiency, " Xi' an University of Architecture and Technology, 2021.
5. Zhang X., "Research on platform optimization design of bus stop section, " Chang' an University, 2019.