Academic Journal of Science and Technology
ISSN: 2771-3032 | Vol. 8, No. 1, 2023

Research on the prediction method of residents' waiting time

--taking the Jiaozuo bus as an example

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Abstract: To accurately estimate passengers' waiting time and select reasonable bus routes to improve travelling efficiency. Based on the real-time bus data, the waiting time is estimated by considering the number of boarding passengers in two time periods: peak and flat period. Firstly, the crawled bus data are cleaned and screened to find out the effective information; secondly, the running time of each road section is extracted; finally, the waiting time for transfer is obtained according to the corresponding model by considering the number of arrivals and the corresponding period. The study shows that the waiting time under different waiting models is more in line with the actual situation, which is convenient for residents to travel.

Keywords: real-time data, bus, transfer time, peak operation.

1. Introduction

The current society of urban development and economic growth has put a lot of pressure on public transportation, affecting residents ' travel. Among them, the ground bus is the main mode of transportation for residents, with large volume and high efficiency. Still, there are problems of vehicle congestion and long waiting times for passengers at the station. The passenger waiting part of the bus service is an important part. As the node of the connecting line, the station is evenly arrived by passengers during the flat peak period. The transfer station is the hub of multiple lines. During the peak period, with the increase in passengers, it becomes the bottleneck of the bus network. The adaptive waiting model for different periods of bus operation can reduce the waiting time for transfers. At the same time, the multi-channel acquisition of traffic big data and location information can use real-time bus data to predict waiting time and improve travel efficiency.

The methods for reducing transfer waiting time and improving public transportation services include optimizing departure intervals scheduling public vehicles [1,2], and developing transportation schedules [3,4]. These methods still need further exploration for the reasonable prediction of passenger flow and the determination of waiting time, even though most of them are related to rail transit and are limited to specific transportation networks. As the network increases, the stability of the algorithm cannot be guaranteed. Waiting time is an important indicator for evaluating the reliability of public transportation services. Huo Yueying analyzed the probability density of passenger waiting time and derived an estimation method for the distribution of waiting time; Complete the algorithm by analyzing the headway and passenger ratio of the vehicle. The passenger flow conference resulted in an extension of passenger waiting time. Cao Zhichao proposed a model based on train schedules and queuing theory to calculate the passenger waiting time of urban rail transit during peak morning and evening passenger flow surges [6]. However, research has strict boarding and alighting schedules for rail transit that are not affected by road conditions. Fu Yanbing derived a formula for calculating the cumulative waiting time of passengers at bus stops based on the random arrival of buses and passengers, indicating that the waiting time is influenced by the interval time between bus arrivals and the frequency of passenger arrivals [7]; Adjusting the departure time of buses to reduce fluctuations can reduce the cumulative waiting time of passengers. However, the study does not explain the bus stopping time at the station, and the unified simplified treatment is zero. To make up for the shortcomings of the above study, this paper proposes a waiting time distribution model based on real-time bus data and considers the impact of passenger flow status on waiting time during peak and flat periods. The waiting time distribution model takes into account the waiting delays caused by the real road conditions at the bus stops, to achieve the purpose of more accurately predicting the waiting time for the convenience of residents travelling.

2. Research area, data sources, and preprocessing

2.1. Research area

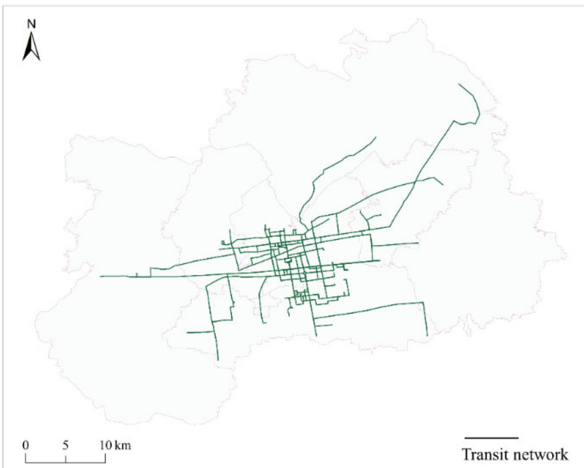

Fig. 1 Schematic diagram of bus routes in Jiaozuo urban area

Jiaozuo is located in the northwest of Henan Province, adjacent to Xinxiang to the east and Jiyuan to the west; The overall terrain is high in the north and low in the south, mostly located in a plain area, with a total area of about 4071km^2. It is a transitional area between the Taihang Mountains and the northern Henan Plain. According to the seventh population census data, the permanent resident population in the urban area is approximately 875000. Jiaozuo focuses on creating the "Public Transport Priority Demonstration City" in Henan Province, establishing a green and civilized development strategy, vigorously developing public transportation, and improving the layout and capacity allocation of public transportation routes. There are over 700 buses and 42 bus routes in the urban area, with a total operating length of over 600 kilometres and an annual operating mileage of 28.8 million kilometres. Buses are sent from the urban area to surrounding areas, with regular routes, express routes, tourist routes, and regional routes. The urban bus route map is shown in Figure 1.

2.2. Data Source and Preprocessing

The coordinate system of the Jiaozuo urban area adopts the plane coordinate system CGCS2000_ 3_ Degree_ GK_ Zone_ 38. The maps used include the Open Street Map (OSM), Baidu Map, and Gaode Map. The geographic coordinate systems (GCS) of these web maps are WGS-84 (GPS coordinates), BD-09 II (Baidu coordinates), and GCJ-02 (encrypted coordinates of the National Survey Bureau). Finally, unify the coordinate values into GPS coordinates import vector features, and map data into the ArcGIS database. As shown in Table 1.

Tab. 1 Data Sources

Data category	Source	Content	Remarks
Administrative divisions	National Basic Geographic Information Center	Boundary of counties and cities in Jiaozuo Bus route ageing site	Surface elements
Bus operation data	Jiaozuo Bus Network	Real-time running trajectory data of buses	Python crawls data in JSON format
Bus line network	Baidu map	The actual running route of the bus	Line features
Station data	Baidu map	Bus Route Time Effective Stop	Point element

3. Research Method

3.1. Waiting time model without considering the number of passengers arriving at the station

Passenger waiting time is influenced by both passenger arrival characteristics and vehicle arrival characteristics. Taking the range of passenger waiting time at the station as the boundary, there is no need to wait and wait for the length of a departure interval. Any waiting time in this waiting time range is reasonable waiting time, to the bus departure interval for the value of the range, each passenger arrival time is equal to the possible, with the specific moment having nothing to do only with the length of the waiting time. At this point, the passenger arrival time obeys the uniform distribution, its mathematical expectation is half of the departure interval, that is, the average waiting time for passengers. Figure 2 for the passenger waiting time expectation solving diagram.

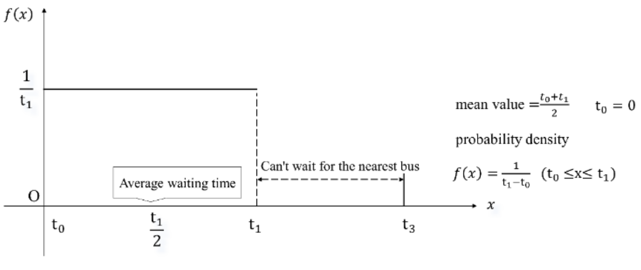

Fig. 2 Flow chart of bus transfer algorithm

3.2. Waiting time modelling considering the number of passenger arrivals

The stochastic process {N(t), t≥0} is a counting process. N(t) is the total number of events that have occurred up to the time t, which is represented by the t function. There are two ways to describe it, one is according to the interval of events, and the other is the total number of events that occur from the event to a certain time. The two description methods describe the event features from different perspectives, and the effect is the same, as shown in Figure 3. The description method of point process $\{X_n, X_{n+1}\}$ can define the occurrence of events on different time scales, m (t) = λt means that events occur λt times in (0, t). Time interval $\{X_n\}$ describes the process, $X_i = t_i - t_{i-1}, (\mathrm{i} = 0, 1, 2, \ldots\ldots)$ denotes the time interval before and after passengers arrive at the station; the mean value m = 1 / λ, λ represents the arrival rate of the event, the number of events per unit time; then m represents the time interval, and the time tends to infinity.

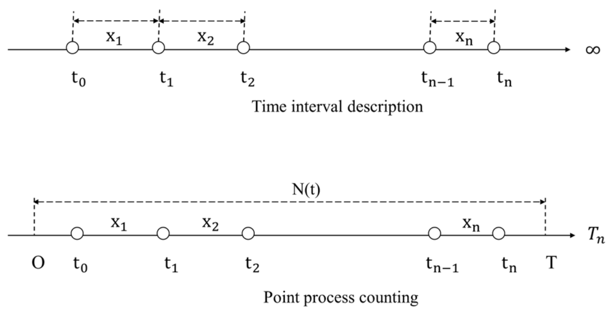

Fig. 3 Two description methods of random events

N (t) as a function of time t follows a Poisson process, and the number of passengers arriving at the station is considered as a Poisson flow. The probability of reaching K passengers within a time of length t:

$$P\{N(t) = k\} = P_k(t) = \frac{(\lambda t)^k}{k!} e^{-\lambda t} (\mathrm{k}=0, 1, 2, \cdots\cdots) \quad (1)$$

In the formula, λ > 0 is the strength of the Poisson process, which represents the arrival rate and the number of passengers arriving at the station per unit time; N(t+s)-N(s) means that there are λt passengers arriving at the station in the time interval (s, t+s) The passengers are independent of each other, and the number of passengers arriving at the station increases with the passage of time.

The average number of passengers arriving at the station :

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The average number of passengers arriving at the station:

$$E(X) = \sum_{k=0}^{\infty} x_k\, p_k = \sum_{k=0}^{\infty} k e^{-\lambda t} \frac{(\lambda t)^k}{k!} = \lambda t \sum_{k=o}^{\infty} P(X = k) = \lambda \quad (2)$$

The probability of passengers not arriving at the station during T time :

$$P\{X \geq t\} = P\{N(t) = 0\} = P_0(t) = e^{-\lambda t} \quad (3)$$

The distribution function of passenger arrival time X after T time :

$$F(x) = p\{X < t\} = 1 - e^{-\lambda t} \quad (4)$$

The above equation is the distribution function of the exponential distribution, and its probability density is :

$$f_x(t) = \lambda e^{-\lambda t} \quad (5)$$

The above analysis is based on the Poisson process, so the time t ≥ 0; including the case that the passenger did not arrive at the station. Take the value of the interval for the time interval, is the continuity of the distribution function, from the discrete Poisson distribution point process into a continuous exponential distribution of the interval, because the two descriptions of the stochastic process are for the same problem, so there are: the passenger arrival process for the arrival rate of λ is a Poisson process, then the passenger arrival time interval is independent of each other and obeys the parameter λ of the exponential distribution, from which the passenger can be calculated the average waiting time.

When the number of passengers arriving at the station obeys the Poisson distribution, the time interval t of successive arrivals obeys the exponential distribution, that is, the probability density of random arrival of passengers in the interval [h] between two adjacent cars is f $f(t) = \lambda e^{-\lambda t}$.

The time expectation of passengers waiting at the station during the period :

$$E(W) = \int_0^{h} (h - t)\, \lambda e^{-\lambda t} dt \quad (6)$$

Average waiting time for passengers:

$$E(W) = h - \frac{1 - e^{-\lambda h}}{\lambda} \quad (7)$$

Figure 4 shows the solution of the average waiting time for passengers.

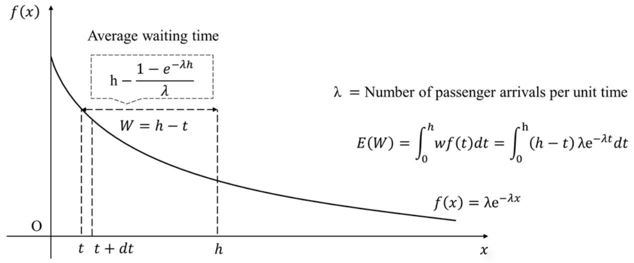

Fig. 4 Calculation of waiting time-based on the number of passengers

4. Bus running time

The real-time data of public transportation is the line data and station departure and stop data of the Jiaozuo urban area on May 19, 2021 (working day). By using web crawler technology, approximately 400000 driving records were obtained during the operation period, and 42662 valid information was obtained after data cleaning. The bus data returned from the website can be both up and down. In order to match the order of the station coordinates obtained from Baidu Maps API, a one-way route is selected. Then, decrypt the data and save it in clear text in JSON format, segment, filter, simplify the structure, integrate redundancy of key fields, and finally obtain the form of effective fields, which are stored in the database. The content of the bus data table is finally integrated as shown in Table 2.

Tab. 2 Bus operation data structure table

Field Name	Data type	Describe	Instantiation
ID	Int	The self-increasing record number of bus return data	34135
Bus number	Float	Identification code for each bus	2707
Previous Station Number	Float	The previous station in the sequence of adjacent bus routes	12
Rear station number	Float	The next station in the sequence of adjacent bus routes	13
Previous station time	Time	Departure time of the previous station	06:42:29
Post station time	Time	Entry time of the next station	06:44:37
time difference	Int	The time difference between the two stations and the time it takes for the two stations to operate	128(s)
Lng	float	113.197516	Site Longitude
Lat	float	35.239466	Station Latitude
OnStation	bit	1	1 means on station, 0 means running
update time	int	1621374900143	Synchronization timestamp, identification code

With the continuous integration of public transport system and information technology, the accuracy and effectiveness of bus arrival time has become an important factor in measuring the operation status of bus lines. Most cities use positioning technology to establish a bus information release platform, and passengers can query the current bus operation status in real-time through the APP application. However, for the running time of the vehicle between the stations and the final arrival time, the bus line can not accurately feedback to the user, which makes it difficult for passengers to choose the right travel route. If more accurate information can be obtained in these two aspects, passengers can reasonably arrange their own travel, reduce waiting time, and improve their trust in public transport.

The time difference between the two stations spent during the operation of the bus is the running time of the road section. The running time acquisition of specific road sections is summarized as follows :

(1) The time cost of obtaining bus data between adjacent stations is obtained by interval values of 0 and 1 in the station field. The bus is represented by 1 at the station and 0 during operation. The cumulative time of 1 occurring continuously can be recorded as waiting time at the station;

(2) The time and location data transmitted by the onboard GPS to the central management platform has a certain time interval, in seconds. The time difference between consecutive adjacent stations in and out of the station status is the running time of the road section;

(3) When calculating the section time of the same route, first consider the same bus number data value to ensure the continuity of the stations; Secondly, it is necessary to complete the missing station data, using Baidu Maps, the "This Journey" app, and existing bus data as references to improve the station information of the entire route and obtain the time cost of each section. Figure 5 is a graphical representation of processing single-line data.

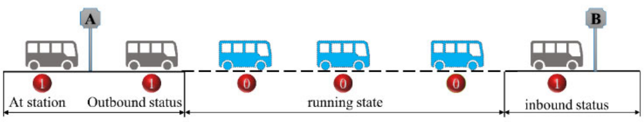

Fig. 5 Bus operation status diagram

According to the bus running speed and the time spent, the bus running time between 6:00 and 22:30 is divided into several periods. The morning peak is 7:00-9:30, the evening peak is 17:00-19:30, and the rest of the time is the flat peak period.

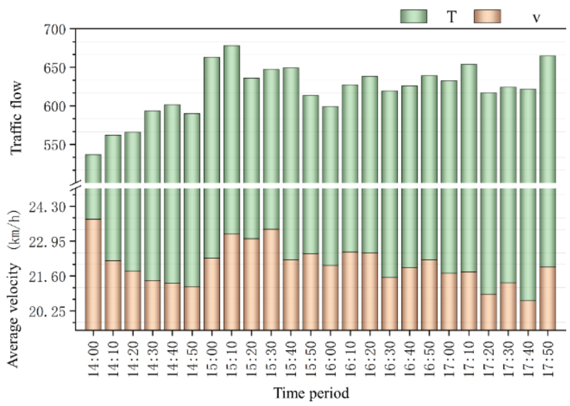

Fig. 6 Comparison Chart of Bus Operation Speed and Traffic Flow during Peak Period

From Figure 6, it can be seen that there is an increase in vehicles entering at 18:00 and 15:10, but the operating speed is significantly slower at 18:00. According to the summer schedule in Jiaozuo, these two-time points are the peak points for commuting, and before the evening peak, a large number of vehicles began to emerge on the road, slowing down the driving speed. For different operating periods, residents can accurately estimate their waiting time and choose appropriate routes to avoid congested road sections.

5. Passenger waiting time

At present, the number of residents ' travels is increasing and the scope of travel is expanding. If travel cannot be completed by direct access, transfer becomes a must. The transfer distance, transfer time, and transfer convenience of passengers also affect the attraction of the entire bus system. Bus transfer is a way for passengers to transfer from one line to another line before and after the connection and continuous conversion to achieve the purpose of travel. Therefore, the transfer involves more lines and stations and requires the location and time information of getting on and off the train, that is, the average waiting time of the transfer station. In a transfer, if the two lines have repeated sections, the station on the section is the transfer station. The completion of a transfer is divided into two stages: the first stage is from the boarding point to the transfer station, and the second stage is from the transfer station to the destination point; according to whether the drop-off point of the previous stage to the boarding point of the next stage is the same station, it is divided into two types: the same station transfer and the different station transfer, as shown in Figure 7. Among them, the same station transfer refers to the transfer of the target bus line at the same station after the passengers get off the bus; cross-station transfer means that passengers need to walk to other stations to transfer to the target bus line after getting off the bus.

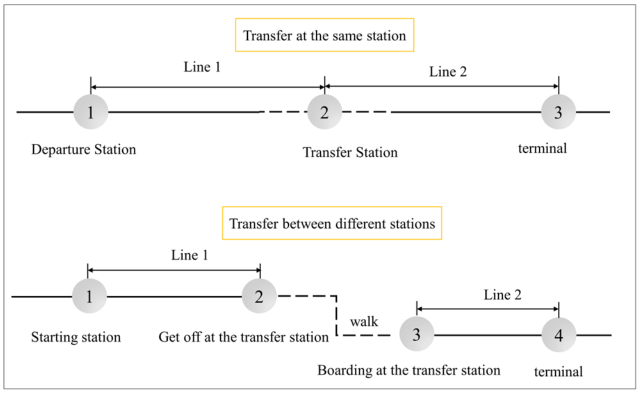

Fig. 7 Transfer diagram

Tab. 3 Relevant information table of transfer stations

Site Name	Number of routes through	Site serial number
Tai Chi Sports Center	2	11.23, 27.28
Municipal Taxation Bureau	3	12.12, 27.26, 35.11
……	……	……
Second Hospital	16	2.01, 16.12, 7.01…36.16

In order to save travel time and achieve punctual boarding, it is necessary to plan appropriate transfer routes and waiting times. The results of the bus route transfer search are stored in Table 3, which includes more than 260 transfer stations and related routes such as People's Hospital, Bus Terminal, and Shanyang Mall.

The information table related to transfer stations stores the number of bus routes passing through stations and the attribute values of each station, which is the core table for bus transfer queries. Excessive transfer times can increase passenger travel time and energy consumption, and reduce the happiness of public transportation. In terms of transfer frequency, the annual report of relevant transportation statistics shows that the average transfer frequency of daily travel for urban residents is 1.3 times [8]. Considering the urban scale and public transportation system of Jiaozuo City, the transfer mentioned in the article is a one-time transfer.

The total time required for passengers to complete a trip by bus mainly includes the following parts: the time from the departure point to the station, the bus waiting time, the travel time, the transfer time and the time from the station to the destination. If passengers can basically judge the length of the whole travel chain before departure, they can choose the best travel plan according to the comprehensive consideration of the degree of urgency and cost of travel. The travel chain can be described as Formula 8. Line 1 and Line 2 transfer at the same station, and the time spent on two consecutive sections is :

$$T_{1-2} = T_{line\ 1}+T_{wait}+T_{transfer}+T_{line\ 2} \tag{8}$$

In the equation:

$T_{line\ 1}$ —— The travel time of the previous bus route 1 on the road section;

T_{wait} —— the time during which passengers wait for Line 1 at the transfer station during the time period;

$T_{transfer}$ —— There is no time difference between the front and rear lines at the transfer station, which can also be recorded as a small transfer walking time and ignored as 0;

$T_{line\ 2}$ —— The travel time of the next bus route 2 from the transfer point to the exit point;

Based on the above analysis, the key to determining the transfer time is to determine $T_{line\ 1}$, T_{wait} and $T_{transfer}$.

(1) Determination of $T_{line\ 1}$. According to the existing real-time bus operation data, the running time between the two stations can be obtained.

(2) Determination of T_{wait}. The waiting time of passengers at the bus station is affected by the departure interval of the bus and the passenger flow at the station. The departure interval can be obtained according to the bus operation data. According to the knowledge of statistics and probability, the distribution of passenger arrival time is calculated. The larger the departure interval, the longer the waiting time; whether to consider the passenger arrival rate depends on the peak period of the bus operation, and the POI attribute and distribution characteristics near the station are also the influencing factors.

(3) Determination of $T_{transfer}$. According to the transfer station information table and the shortest path algorithm, the running time of the front and rear stations is obtained. When the passengers need to walk to different stations to realize the transfer, the walking time should be added. When transferring at the same station, because $T_{line\ 1}$ and T_{wait} have been determined, the time of transfer switching can be obtained according to the time equation of the two sections.

When passengers arrive at their destination and cannot meet their demand by taking a single bus, they need to transfer to another bus route. The transfer time includes the walking time between stations and the waiting time at stations. The walking time depends on the pace and distance between stations, while the waiting time is related to factors such as the arrival time of passengers and buses; Compared to the collection of walking time, it is more difficult to obtain waiting time in real life. The common practice is to model the average waiting time of passengers. For example, after obtaining information on bus operation time, statistical theory calculation methods are used to first study the distribution pattern of passenger arrival time at stations, and then establish corresponding average waiting time models based on different periods of bus operation.

In the study of bus waiting time, some scholars have pointed out that when the passenger arrival obeys the uniform distribution, or the departure interval is less than a certain threshold, the average waiting time of passengers is half of the departure interval. In addition, foreign scholars have studied the regression function of passenger waiting time and bus departure interval. The relationship between average passenger waiting time and departure interval is $W=2.34+0.26\mu$, where W is the average waiting time and μ is the departure interval [9]. In addition, the general idea of calculating the total waiting time of passengers at a certain station is as follows: firstly, the time distribution law of passengers arriving at the station is studied; secondly, the probability density integral of the fitted distribution is used to obtain the expectation of per capita waiting time; finally, the total waiting time of passengers is calculated by multiplying the total number of passengers arriving during the study period [10]. This method requires passenger flow per station as a support.

Considering the existing bus real-time data and related site information in this paper, the bus arrival time and the attraction of POI near the site to passenger flow are known. Based on this, the corresponding waiting time model is established according to the peak and flat peak period of bus operation, and the results are obtained by comparative analysis of examples.

5.1. Waiting for the bus during flat hump hours

(1) Model Assumptions

The entire time from the departure of the first bus on the route to the last bus stopping at the terminal station is taken as the bus operation time, and the peak period is divided according to the operating speed and passenger flow distribution characteristics. Determine the corresponding waiting time for the time period. Simplify the actual problem before modelling to make the calculation data standardized and operable. The model values approximate the description of real-world problems to the greatest extent possible.

Based on the obtained operational data table information, the following assumptions are made:

① Passengers waiting for buses at bus stops are not stranded;

② Passengers arrive at the station sequentially and independently of each other;

③ Passengers arrive at the station and queue up to wait for the train. When the train stops, it will arrive first served first served;

④ Take the average departure interval of the same line at the same time period as the departure frequency;

⑤ Divide peak periods based on bus operating speed and passenger flow, with the same departure frequency during the same period;

⑥ The passenger flow of the station is only related to the peak period, the surrounding POI attribute and the distance between the stations.

(2) Model establishment and solution

The waiting time of passengers is influenced by two factors: the arrival characteristics of passengers and the arrival characteristics of vehicles. The boundary is the range of waiting time for passengers at the station, where there is no need to wait and the duration of waiting for a departure interval; Any waiting time within this waiting time range is a reasonable waiting time, with the bus departure interval as the value range. The arrival time of each passenger is possible, regardless of the specific time and only depends on the waiting time. At this point, the arrival time of passengers follows a uniform distribution, and its mathematical expectation is half of the departure time interval, which is the average waiting time of passengers.

Example 1: Taking Jiaozuo City's No. 12 bus transfer to the No. 23 bus as an example, the arrival time of each station is obtained from the bus operation data table. The No. 12 bus departs from the first station and arrives at the transfer station fire brigade at 4 stations. After getting off the bus and waiting for the No. 23 bus, it passes through 2 stations and arrives at the destination. Passengers ride during the peak period of public transportation, using a uniformly distributed waiting time model; The time taken to pass through the section between stations is the average running time of the day during the peak period. According to equation (8), the passenger sharing time from the starting point to the destination is 20.7 minutes. Figure 8 shows the travel behaviour of passengers during a certain period of time. Route 12 has a lower frequency of departure, takes a longer total time to pass through the station, has a shorter distance to the same station, and the walking time is ignored.

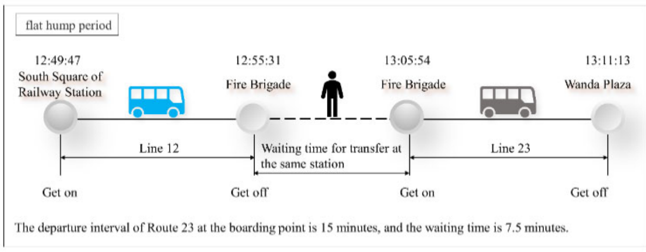

Fig. 8 Diagram of passenger transfer time in peak period

5.2. Waiting for buses during peak hours

Queuing theory obtains the statistical laws of the expected queue length, waiting time and other quantitative indicators by counting the arrival time interval and service time of the service object [11]. If the bus station is regarded as a service desk, the arrival of passengers is regarded as an input process, and the time interval between two adjacent cars arriving at the station is regarded as the service time, the process of passenger travel can be described by queuing theory knowledge. The description of the bus service queuing theory problem is as follows :

(1) Queuing mode: When passengers wait in line, they obey the first-come-first-served waiting mechanism.

(2) Service time: bus service belongs to the combination of a single queue and a single service desk. When passengers wait in line, the time difference between the two cars before and after the stops.

(3) Input process: the process of passengers arriving at the bus station, passengers arrive at the station within time t and are independent of each other.

Example 2: Taking Jiaozuo City Bus No.28 to No.11 and No.10 as examples, (Figure 9) illustrates the two situations of transfer between different stations, and sets the bus system and walking speed according to corresponding national standards. During the travel process, add walking time and waiting time, and take the bus during peak hours. Considering the passenger flow at the station, the travel time of the route is obtained from bus operation data.

Scenario 1: Passengers get on the bus at Jiaozuo Sports School, take Bus No. 28, pass through 2 stations, and get off at the transfer station, China Construction Bank. They then walk to the opposite station and take Bus No. 10, pass through 8 stations, and get off at the destination city people's congress. During this trip, the total bus operation time was 20.3 minutes, the waiting time at the station was 9.2 minutes, and the maximum walking time to the station was 1.5 minutes. During peak passenger travel, it took 10 stops and a total of 31 minutes.

Scenario 2: Passengers who get off at Jiaozuo Sports School need to transfer to another route to reach their destination. At this point, they need to walk to Wugongqiao Station to wait for a suitable bus. The time interval between getting off in the previous stage and getting on in the next stage cannot exceed the maximum allowable time, that is, the sum of getting off time and walking time is greater than the arrival time of the transfer station route. If it exceeds the time limit, waiting for the next bus will become a simple waiting time for the transfer. It is known that the time for passengers to arrive at the transfer station is 18:09:46, which is less than the arrival time of Route 11. Therefore, transferring from another station can be achieved. When passengers need to arrive at the expected destination station and join the corresponding route, the waiting time and section operation time can be obtained to determine the entire travel time. Introduce the details of the calculation process in the following description, and reveal the travel chain concept advocated by the public transportation system afterwards.

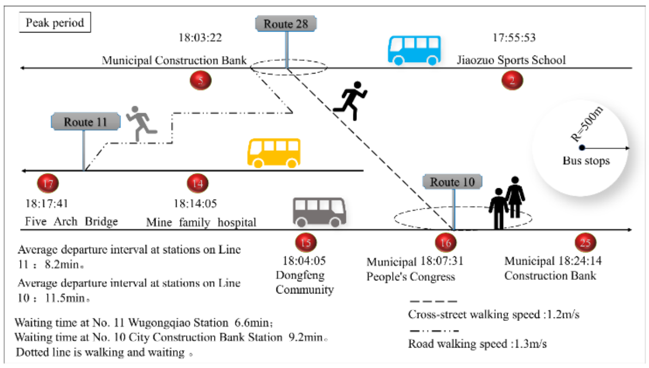

Fig. 9 Passenger transfer road map during peak hours

The "Code for Urban Road Traffic Planning and Design" (GB50220-95) specifies the indicators for the planning and layout of urban public transportation, pedestrian transportation, and urban road systems [12]. Because this regulation has been implemented since 1995, most urban road traffic has been completed in accordance with the regulations, including the installation of public transportation stations, with a transfer distance of no more than 50m in the same direction and no more than 100m in the opposite direction on road sections; When setting up opposite stations, they should be staggered by 30 meters in the direction of the vehicle's forward direction; The distance between urban bus stops is 500~800m. The "Urban Comprehensive Transportation System Planning Standard" (GB/T51328-2018) points out that the transfer distance between different lines of urban public transportation should not exceed 200m, and the transfer time should be controlled within 10 minutes. The standard unanimously proposes that the service area of bus stops, calculated with a radius of 500m, should not be less than 90% of the urban construction land area. Currently, the coverage rate of 500m bus stops in domestic cities has been basically completed [13].

The first stage of the goal of urban traffic development mainly meets the motor vehicle capacity and carries out road construction; now more attention is paid to residents ' travel planning, encouraging public transportation, walking, and moderate intervention in cars. The road space is allocated to more people, with bus priority, supplemented by walking, forming a ' bus and walking ' mode of travel. A large number of studies and literature have shown that the walking speed of pedestrians crossing the street is 1.2m / s [14-17]. From the perspective of the passenger flow on and off the bus in a day, according to the actual situation, the number of people on the bus at a single station is 5 people waiting for the peak period; in ArcGIS, the length of the road section between each station can be obtained through the attribute information of the line data table. The average walking speed of the pedestrian is 1.3 m / s, and the walking time on the road is obtained. If there is no corresponding road data, the time is calculated according to the specified service range of the station. The average distance of the selected station is 500 m, and it takes 6.4 minutes for pedestrians to reach the bus station for transfer preparation.

Based on the above analysis, the pedestrian walking time can be further calculated. Under the condition of the example two station, regardless of the travel time consumed by the influence of traffic signals, passengers walk at least 60 m from the drop-off point to the transfer point, the walking time spent is 50 s, the walking time of the opposite transfer is not more than 1.4 min, and some environmental parameters are introduced. Pedestrian transfer needs to walk 1.5 min. In the case of the same station, the maximum walking time takes 42 s, so it can be omitted.

From the model characteristics can be seen, that as the number of people waiting for the bus at the station continues to climb, the passenger waiting time is closer to the maximum value of the route before and after the neighbouring bus running time difference. When the bus operation is in the peak period, it is necessary to fully consider the passenger flow around the station and the number of people waiting at the station. For example, university towns, community clusters and commercial centres, where the crowd is more concentrated; when encountered in the peak period the passenger flow is bound to increase, the simple use of the time model of Example 1 to calculate the waiting time will have a bias, so there is the introduction of Example 2 as a reference for the waiting time during the peak period, so that there are different periods of time corresponding to the time model, so that the waiting time is more closely related to the reality.

6. Conclusion

This paper obtains the running time between the bus line stations in Jiaozuo City through the bus operation data of a certain day, which is real and effective. According to the real-time bus data, the waiting time on different line stations is obtained. The main factors affecting the waiting time of passengers are the departure interval of the bus and the time distribution of passengers arriving at the bus station. The waiting time is calculated by the mean method, and the weighted average time is more universal. The waiting time is solved by establishing different models according to the probability distribution of passengers arriving at the station. Combined with the real-time operation data of the bus, the departure frequency no longer adopts the adjacent time difference between the two vehicles at the first station. Taking the previous station of the waiting station as the object, the time difference between the successive arrivals is used as the departure interval of the line. According to the characteristics of passenger flow and vehicle speed, the bus operation stage is divided into two periods: peak period and peak period. Taking the probability distribution of passenger arrival time as the starting point, the uniform distribution waiting model is used in the flat peak period, and the exponential distribution waiting model is used in the peak period.

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