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The Route Planning on Campus Bus in H University

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Abstract

In recent years, the university development is at the expansion period. As the important part of the overall planning process, campus traffic planning gets highly consideration as to the university builders. The optimization of the transportation system will bring convenience and safe experience to the school staffs. This paper analyzes the current situation of campus traffic organization in H university campus, and establishes a trip map to the traffic network. Finally, based on the basic principles of traffic planning, we designed campus bus routes and sites. By using of cost analysis, we also design the optimal starting frequency, which optimizes the campus traffic system.

Keywords

Campus Traffic Planning, Route Network, Cost Optimization

1. Introduction

Since the new century, the rise of college enrollment rate has made the number of teachers and students in colleges and universities continually increase. When the campus constantly enriches and perfects its education environment, it also results in some problems such as overlong traffic routes among functional areas in campus, travel inconvenience and so on. Aiming at the mixed-traffic of many kinds of traffic inside the campus, Lin Zhen (2007) [1] researches and puts forward some measures, including campus road network transformation, mixed traffic separation, parking layout optimization, pedestrian space setting and guidance of external traffic. According to the type of spatial layout of college campus, Xu Junbin (2012) [2] divides it into four categories: annular space layout, strip space layout, grid space layout and free-form space layout. Aiming at the actual situation of road traffic in our country, Yang Dongyuan and Liu

Zhiqian (2008) [3] respectively analyze the factors influencing the stop time of bus stop and establish the corresponding empirical formula. When studying the stop time of stations, Mao BaoLi (2009) [4] has considered the effect of vehicles from outside of the campus on buses and analyzed the effect of traffic flow and running speed on the stop time of bus stop, and he also has researches the queuing time of outbound buses in-depth.

In order to solve this problem, H University (Wushan Campus) opened Campus Bus Line 2 in April 2015 and since being opened for more than two years, it has improved travel efficiency of teachers and students in campus to a certain extent. H University now have two bus campus routes: Line 1 and Line 2, Line 1 service between North area and South Gate, it mainly to meets the travel needs of North area students and faculty; Line 2 service between South area and the East area, it mainly meets the travel needs of staff in the South area as well as East area. However, there still exist many shortcomings. This paper adopts questionnaire survey to summarize the shortcomings of the current campus bus system, allocates the traffic volume of the campus road network based on Wardrop user equilibrium theory model, and finally designs a new bus route map, and uses cost analysis method to establish a new bus operation schedule.

2. Survey about Campus Travel Demand and Problem Analysis

2.1. Analysis on Campus Status

H University covers an area of more than 2940 thousand square meters. The campus is divided into two campuses, and the Wushan Campus is located in the Shipai College Area of Tianhe District, Guangzhou City, and is the main campus of this study. Wushan Campus covers an area of 182.6 hectares (including military land in south front door) and is founded in the 1930s, and it has experienced development and construction in different stages of more than seventy years before and after liberation, and formed architectural styles in different stages and distinct layout of function division in the process of constant evolution.

There are three main parts of people in the campus: full-time students, faculty members and administrative staff. According to the statistics report of 2014, North Campus has 20,723 undergraduates, 13,276 doctorial candidates and postgraduate students and 1531 overseas students, totaling 43,862. It is expected to reach about 5000 people by the year of 2020: 5590 faculty members, and according to the coefficient of dependent 3.0, the faculty members (including family members) are about 16,000. In addition, there are about 1000 administrative staffs and the total of faculty members is about 19,000.

The planning of campus traffic is the subsystem of the whole college campus planning and construction. The division of functional area in each campus is conducive to the implementation of the campus traffic organization planning, and the planning and design of traffic organization should also make coordination with various functional areas. The relationship between functional areas is

carefully analyzed, and the division of functional area in North Campus is confirmed with the combination of use properties of campus land as well as landform. At present, it is divided into five functional areas: central area, north area, west area, south area and east area, as shown in Figure 1. The distance between each functional area is shown in Table 1.

2.2. Questionnaire

This questionnaire survey is carries out from April 5th to 10th, 2017, and has completed 425 valid questionnaires, including 143 in the west area, 127 in the north area and 155 in other areas. It mainly investigates the characteristics, demand and intention of the present situation of campus travel.

From Table 2, it can be seen that the users of roads are mainly divided into

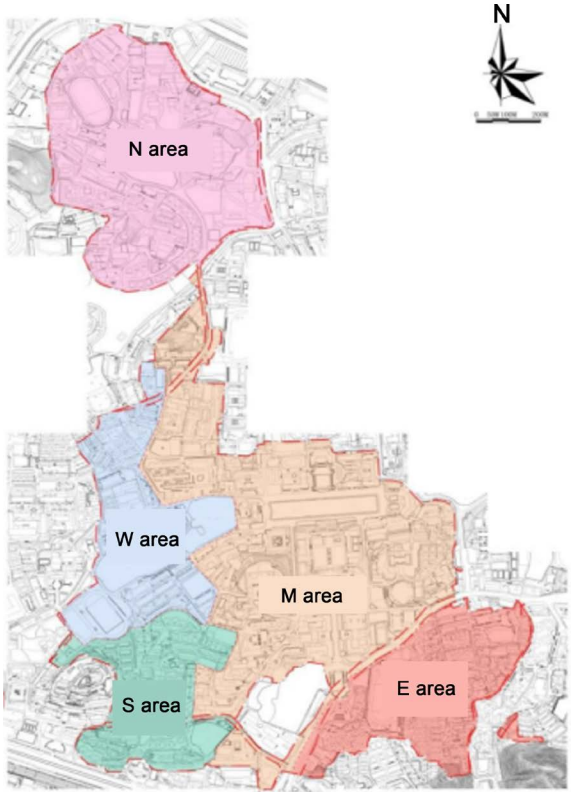

Figure 1. Partition map of H University (H University capital construction department).

Table 1. The distance between each functional area.

Distance (km)	N area	W area	M area	S area	E area
N area	-	1.5	1.2	2	2
W area	-	-	0.6	0.5	0.9
M area	-	-	-	0.9	0.8
S area	-	-	-	-	0.7
E area	-	-	-	-	-

pedestrians, motor vehicles and non-motor vehicles. As the main pedestrians of campus traffic behavior, it includes students, faculty members and social visitors, whose travel modes are walk, bike, electric car, campus bus and car. According to the investigation, the travel modes of the students are mainly walk and bike; the travel modes of faculty members and social visitors are mainly motor vehicle.

According to suitable distance for walking, people will feel tired after walking more than 500 m. Therefore, the travel of more than 500 m in the school is defined as long-distance travel, and that of less than 500 m is short-distance travel. The different travel distances frequency is shown in Table 3.

From the above table, it can be seen that there is slight difference between administrative staffs and teachers. Long-distance travel and short-distance travel of students on weekday respectively are 3.3 times a day and 4.2 times a day, while they significantly reduce on weekend. Therefore, this paper focuses on analyzing the travel characteristics of students and teachers during the workdays.

According to the survey, in Figure 2, the travel peak of students on campus is

Table 2. Main travel modes on campus of campus traffic (%).

	The car	School bus	Electric car	Bike	Walk
Student	0	6	0	32	62
Faculty member	60	1	8	12	19
Visitor	73	5	0	2	20

Data collection is based on questionnaire survey.

Table 3. Frequency distribution of different travel distances (sub/d).

	Administrative staff	Teachers	Students (working day)	Students (weekend)
Long-distance travel frequency	2.9	3.3	3.3	2
short-distance travel frequency	3.1	2.8	4.2	2.7

Data collection is based on questionnaire survey.

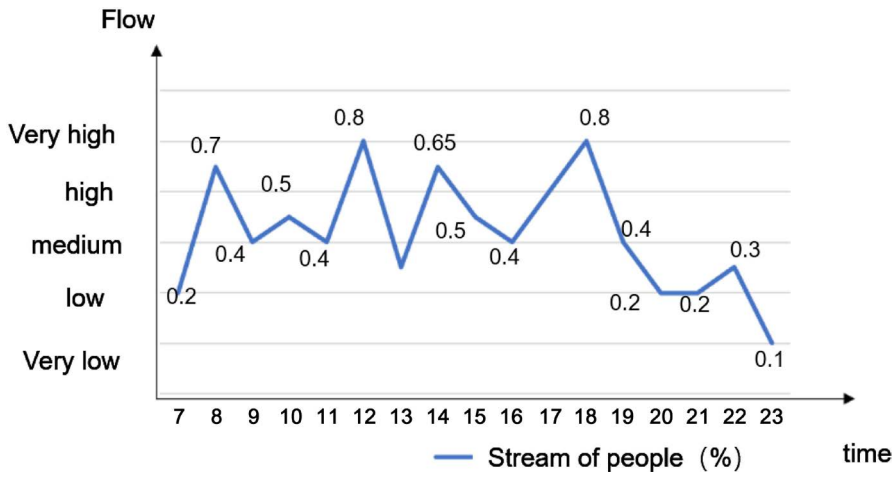

Figure 2. Campus people flow peak chart (Data collection is based on questionnaire survey).

mainly concentrated in the time of 8 a.m. before the class and 12:00 noon after class. From 11:30 to 12:00, it is the time period when students intensively go for the lunch; from 14:00 to 14:30, it is the peak of attending classes in the afternoon, which is basically the same as the peak in the morning; from 17:00 to 18:00, it is the time period when students intensively go for dinner, and after that, the traffic behavior of students is return to the dormitory for rest; From 18:30 to 19:00 is the main travel time of self-study in the evening; After 21:30, it is a time period when students return to the dormitory to sleep in succession.

2.3. Analysis on Travel Problem

The travel problem of this campus are as followings:

- Can't meet the demand of travel in peak hour and Campus Bus Line 1 is the only bus routes for the travel in the north area. in the peak hours of attending and finishing classes, it can't meet the travel demands of students and staffs in north area and also can't meet the general travel demand of some people, such as from residential area in south area to other areas, from students' dormitories in west area to outside school as well as infirmary, residential area of staff in east area to public teaching buildings.
- The distance of Campus Bus Line 1 between Zhongshan Station Baibu Station is less than 200 m, and the most area covered by Baibu Station also can be covered by the area of Zhongshan Station.
- There is a cross between South Changjiang Road to North Changjiang Road and Dongguan Village Road, and it is a downhill from South Changjiang Road to the crossroad, which easily cause dangers. Roads on campus are mainly coexistence of people and vehicles, and the roads are not wide enough with a result of traffic jam.
- Problems of campus bus itself. Campus Bus Line 1 has a low punctuality rate, unfixed cycling time and higher interval service time. Newly-built Campus Bus Line 2 mainly serves teaching staff with few seats, and its departure frequency is less than half of the prescribed one, and many students are not able to enjoy the benefits brought by the new opening line.

3. Campus Transportation Model Construction.

3.1. Travel and Attraction Distribution of H University

Travel and attraction survey is to investigate the starting point and destination of people's travel on campus, and the purpose is to analyze the current situation of the traffic flow relations between different traffic areas [5] and provide basic data for future traffic volume forecast and check. According to the functional layout of different buildings within the campus, it is divided into 12 traffic areas, as shown in **Table 4** and **Figure 3**.

3.2. Demand Analysis

Traffic area and road network are the simulation of the actual road network in

Table 4. Overview of campus functional areas.

Serial number	Main functions of community	Number of people/floor area (person/m^2)
1	student dormitory in north area	8218/303,570
2	teaching area	135/81,939
3	postgraduate dormitory	3667/150,893
4	sports field in west area	234/58,402
5	teachers' residential area in south area	1893/412,845
6	student dormitory in west area	7756/223,876
7	college administration laboratory building.	1834/467,323
8	administrative office	561/156,783
9	library	175/20,654
10	cultural and sports center, kindergarten	785/74,593
11	dormitory group in east area	3852/258,313
12	school office	283/40,738

Data collection is based on questionnaire survey.

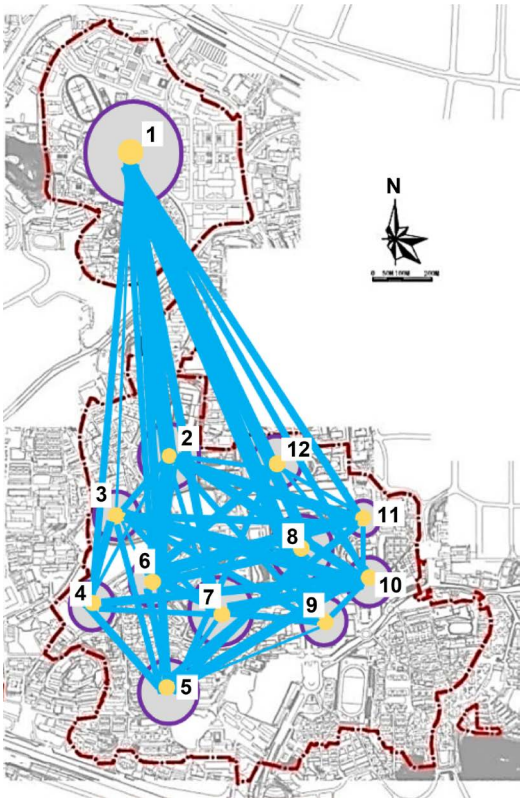

Figure 3. Campus travel flow map.

the form of data, which is the important basis of traffic model. The size and boundary of traffic area, the scope of road network and the section parameters directly affect the accuracy and authenticity of the model. The road network

model is shown in Figure 4. Section 1-22 is the shared road of pedestrians and motor vehicles, of which section 15 is an important pedestrian passageway.

According to the characters of campus travel, it can assume the future travel purpose and travel frequency of teachers and students remain the same, and original unit method is used to respectively calculate the original unit of generation and attraction, and then according to the value of travel generation and attraction gotten through the forecast of attributes such as generation original unit and attraction original unit as well as population and area, allocate travels of each community to road network and travel allocation model to calculate the traffic volume in each section and finally get the data of each section. The Wardrop Equilibrium Theory model is expressed as follows:

$$\text{When} \quad L_k^{pq} > 0, \quad c_k^{pq} = c^{pq}, \quad \forall k \in K^{pq}, \quad \forall pq \in \Omega \tag{1}$$

$$\text{When} \quad L_k^{pq} = 0, \quad c_k^{pq} \geq c^{pq}, \quad \forall k \in K^{pq}, \quad \forall pq \in \Omega \tag{2}$$

$$\sum_{k \in K} L_k^{pq} - t^{pq} = 0, \quad \forall pq \in \Omega \tag{3}$$

$$\text{When} \quad L_k^{pq} \geq 0, \quad \forall k \in K^{pq}, \quad \forall pq \in \Omega \tag{4}$$

In the formula, L_k^{pq} is the traffic volume of OD towards pq in the k^{th} path;

c_k^{pq} is the travel time of D towards pq in the k^{th} path;

c^{pq} is the travel time of D towards pq in the shortest path;

t^{pq} is the traffic volume of OD towards pq in shortest path.

From Table 5, it shows the 1 2, 3, 4, 5, 8, 9, 11, 12, 13, 14, 15, 20, 21 road sections have large flow, average daily traffic volume reach from 8000 to 30,000.

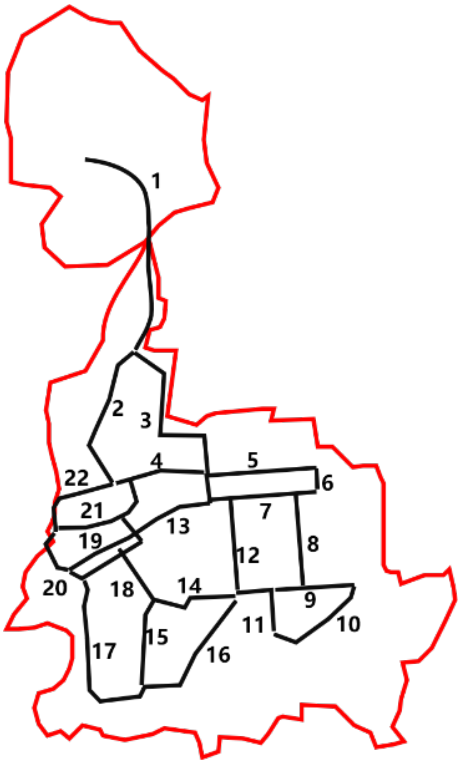

Figure 4. Campus road network model.

Table 5. Student traffic volume distribution results in each section (person-time/d).

Section of serial number	Traffic volume (bidirectional)	Section of serial number	Traffic volume (bidirectional)
1	16,063	12	32,040
2	14,242	13	15,166
3	15,052	14	19,348
4	14,522	15	9348
5	10,837	16	5766
6	5287	17	3919
7	0	18	5254
8	8837	19	6715
9	29,810	20	9110
10	2456	21	2181
11	12,519	22	5102

4. Campus Bus Design Scheme

According to the construction of road network in the previous chapter, we consider to improve the deficiency of existing traffic on campus. The improvement of scheme follows the principles to design, and on the basis of new scheme, analyze the characteristics of the route optimization and finally conduct the optimization of operation project towards newly designed route plan, including departure time and the optimization of departure frequency, to maximize efficiency of public transportation.

4.1. Route Design Optimization Principles

1) Follow the principle that route covers main passenger flow corridor

The design of campus traffic route must be consistent with the main flow of people. The people flow on campus OD is obtained by investigating the people's intention to travel on campus. From the analysis on campus traffic network, it can be known that Campus Bus Line 1 covers from the north area to the public teaching buildings, administrative buildings and the flow direction of south front door, however, there is no bus route to cover from the north area to infirmary, from dormitories in west area to Wushan subway and from travels in south area and residential area to college buildings and public teaching area. Thus, when designing route, it should consider these main routes.

2) Principle of moderate length of traffic route

The length of the route should be designed within a reasonable range so that the bus system can be better organized and operated. On the one hand, if the distance between the routes is longer, the average cycling time of the bus will become longer, the bias ratio of time when vehicles arrive the station will

increase, and there will also e many problems when arranging departure frequency; on the other hand, if the route is too short, the users it covers are fewer and the vehicle's cycling time is short, so that the passenger's intention to ride will decrease and the economy is not good. The relevant data suggest the route length is appropriate when the bus runs 5 - 15 km among 20 - 30 min. This paper recommends to adopt the standard of 6 - 10 km.

3) Principle that traffic route covers densely populated areas

Use personnel density heat map to show the data of builders in each area obtained through survey. Heat map adopts EXCEL plug-in and POWERMAP painting. Label west campus, central area, south area and roads in east area or density of dormitory personnel.

4) Principle of lower linear coefficient.

The design of the bus route should also pay attention to the influence of the linear coefficient. In terms of a bus route, the straight line surely is best, just like Campus Bus Line 1 which exists in H University. When designing the round route, the linear coefficient should also be paid attention to. If the linear coefficient is higher, users' satisfaction with the route will be reduced, and the travel time of users will be greatly increased. It is generally believed that the linear coefficient should be between 1 and 1.3.

5) Principle of satisfying the actual environment

When design traffic route, the important aspect which should be paid attention to is the geographical environment of the campus. The terrain of H University is undulating, and its local slope is more than 8%, so when considering route design, it should be considered that the driven routes of the vehicle lie in altitude traverse with slight ups and downs as far as possible.

4.2. Design of Bus Stops

The bus stop setting on campus is a systematic and complicated work. At the beginning of the study about bus stop setting, stations need to be classified clearly firstly. Bus stopover station is the node of transit network. Travelers use the starting point and end of bus, which provides service for the stop of public transport and passengers' getting on or off the bus. The performance of bus stop directly affects the service efficiency of public transport, even the traffic capacity of the whole road. Bus stop can be divided into two basic forms of station: original and terminal station and midway station according to function.

1) Design of original and terminal station

The original and terminal station is the beginning and end of the bus line, which provides service for the arrival and departure of operating vehicles and passengers' getting on or off the bus. At the same time, it also is the place where traffic dispatchers organize the operation of vehicles, drivers have a rest and vehicles are maintained. Thus, the original and terminal station should be close to parking lots of public transport or maintenance factories

and pay attention to be near the existing stations, in order to be easy to transfer.

2) Design of midway station

The midway station should be set on the nodal points of main passenger flow that the public transport route passes, and the average distance between stations is 200 m - 300 m. The station distance of campus population density selects the lower limiting value, and the station distance of the marginal area and the area of people flow choose the upper limiting value. The selection of site should also satisfy the three main functions of vehicle: safe stop, convenient passage and convenient transportation.

4.3. Campus Traffic Route Design

According to the campus traffic route network map and the campus elevation map, we can get the elevation map of the main people flow on campus.

1) The north section of the Hubin, the section of Songshan and the north section of Zhujiang are all at a lower altitude, and also are in the main traffic section.

2) The main routes of travel in south area and the travel routes of residential area in east area have a single direction with little fluctuation in altitude.

3) The selection of original and terminal station is the station of south front gate, and there is a bus maintenance station in the south front gate, and can be transferred to the original Line 1.

After fully considering travel demands of people on campus, geographical factors and design principle of bus route and station, set up a route (as shown in Figure 5) for south front door—Zhongshanxiang—College of Business—No. 15

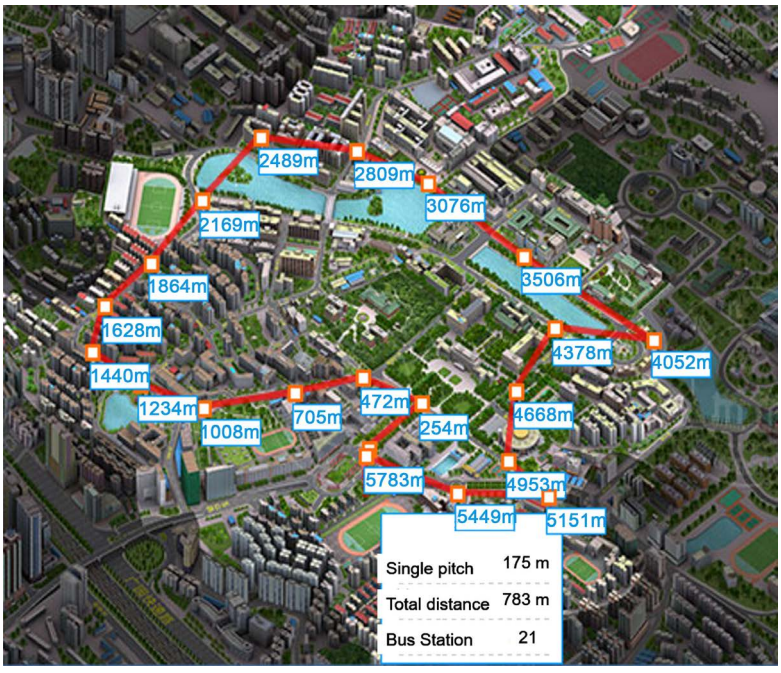

Figure 5. The average distance travelled of the new route.

building (Zhujiang East Road)—complex buildings in west area (crossing of the Yellow River)—No.17 press building—Xi'er Village (crossing of Duxiufeng)—Lijiang Road—stadium in area—Research Two—Research Four—Research Five—No.31 building—Yifu Science Museum—Architectural Design Institute—the dormitory of the national defense students—East eight—Cultural and Sports Center—kindergarten—918 intersection (tunnel portal)—the south gate.

The route has 21 bus stops in total (Figure 5), and the original and terminal station is located at the south gate terminal, a place where is convenient for drivers to have a rest and the dispatching and maintenance of buses. The total length of this route is about 6000 m, and the average length of station is 200 m. According to the bus speed standard: 30 km/h, the time required for a bus to travel around is 25 min.

5. The Design of the Operating Schedule of the Campus Bus

The departure frequency of departure is closely related to the traffic cost. This paper mainly considers the user cost and the operating cost of the vehicle, as follows:

$$C = C_u + C_o \tag{5}$$

In the formula, C is the total cost; C_u is the user cost and C_o is the operating cost.

1) The waiting time cost of the user is:

$$C_u = a_w \left(\frac{\sum_{i=1}^{n} b^+}{f} + \frac{\sum_{i=1}^{n} b^-}{f} \right) \tag{6}$$

In the formula: f is the departure frequency,

b^+ is the waiting time for passengers who get on the bus,

b^- is the waiting time for passengers who get off the bus

The operating cost of the vehicle includes the driver's wage and welfare costs, the fuel consumption and maintenance costs of the daily operation of the bus.

$$C_o = f * P * \left(c_0 + c_1 * N + c_p \right) \tag{7}$$

In the formula, P is the length of the route (km);

c_0 is the initial fixed input cost (yua /km);

c_1 is the variable cost (yuan/km * seat);

c_p id the cost the drivers derive per kilometer (yuan /km).

According to questionnaire survey above, the basic data of cost analysis of Line 2 shows in Table 6. Calculate the user cost and operating cost in different departure frequencies, and look for the optimal departure frequency in a reasonable range to determine the minimum total cost. User cost and total operating cost are show in Table 7.

As what you see in Figure 6, along with the increase in departure frequency, the total cost decreases firstly and then rises with greater falling range and slow rising trend. The total cost is in a lower value when the departure frequency is

Table 6. Basic data of cost analysis of Line 2.

parameter	value
a_w/(yuan/h)	6.74
c_0/(yuan/h)	1.50
c_1/(yuan /km*seat)	0.08
L/km	6.0
N	16.0

(Data collection is based on questionnaire survey).

Table 7. Table of user cost and total operating cost in different departure frequencies.

f	h/min	C_u	C_o	C
5	12	1.4	0.4	1.8
6	10	1.24	0.5	1.74
8	7.5	1.08	0.6	1.68
10	6	0.98	0.65	1.63
12	5	0.91	0.70	1.61
15	4	0.86	0.74	1.60
20	3	0.83	0.79	1.62
25	2.4	0.82	0.82	1.64
30	2	0.8	0.85	1.65

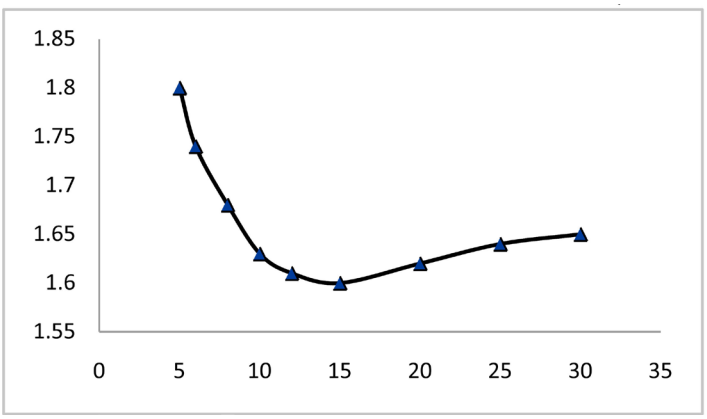

Figure 6. Total cost graph.

among 12 and 15 veh/h.

It is suggested that the departure time in the peak hours is 4 - 5 min, and the departure time in the off-peak hours period can extend by 6 - 8 min properly.

The operation mode adopts the form of bi-directional departure to increase the frequency of the campus bus; use the peak and the flat peak elastic design to increase the departure frequency in the peak and off-peak period. The average stopping time for each station is 30 s, and the time that vehicles travel along the route is:

Table 8. Operating schedule for new Line 2.

Time interval	Route	Departure interval/min	Unidirectional departure frequency	Main function
7:30-8:15	residential area in east area —teaching building	3	15	attending class
8:15-9:40	route around campus	5	18	all travels
9:40-10:15	residential area in east area —teaching building	2	15	attending and finishing class
10:15-11:40	route around campus	5	20	all travels
11:40-12:30	residential area in east area —teaching building	2	15	finishing class
13:50-14:30	residential area in east area —teaching building	3	10	attending class
14:30-16:30	route around campus	5	30	all travel

Run time (min) = distance travelled (km) * 2 (min/km) + number of stations in the route * 0.5 (min/ station) [6]

In theory, the run time is 26min. Consider with the combination of cost, demand and safety. The operation of the campus bus is calculated according to 8 hours. The operating schedule is as Table 8 shows.

6. Conclusion

The reasonable design of campus bus routes can meet the travel needs of campus personnel, and at the same time it can realize the green, safe and harmonious campus traffic. This paper studies the planning and design method of the university campus bus, and conducts travel investigation among teachers and students in campus, analyzes the travel mode, travel distance, travel frequency, travel destination, travel time and people willingness feature. The school personnel travel has summarized as following characteristics: mainly by walking; travel and attractions are concentrated in the teaching area, dormitory area, office area and sports area. This paper also has built the travel model of campus traffic and allocated specific traffic volume to main roads of campus, and then put forward principles that suit campus traffic optimization of H University, including the principle of designing route and stations. The designed routes meet various requirements. At last, the optimized route is proposed to optimize the rate of coverage and operation cost, find the departure frequency after optimization, and propose campus bus design and planning program.

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