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Study on traffic organization for primary roads with super small spacing

X. Gao J. Cai Y. Long Z.A. Song

School of Architecture & Fine Art, Dalian University of Technology, Dalian, Liaoning 116023, China

Abstract

When the primary roads are unable to be set according to the suggested primary road spacing due to special reasons, Chinese planners will often use the method of separating or merging the primary roads; when it matches the suggested primary roads and the traffic pressure is heavy, they use the way of widening roads. Primary roads with small spacing mode where Nagoya, Berlin, and Los Angeles located in are helpful to solve the above problems. The intersection of two adjacent primary roads with small space is regarded as a combined intersection, to analyze the traffic flow; 130-meter spacing primary roads with 4 lanes road simulation model and its road network combination simulation model are constructed, the set OD traffic and simulated OD traffic are compared, and the primary roads with small spacing and its running status in the road network are tested. Primary roads with small spacing has the advantages of flexible network organization, and it is conducive to land development and traffic development. When it does not meet the requirements of the conventional road network spacing or traffic pressure is heavy, it is supposed to combine the actual situation, in-depth study, and prepare road network planning according to local conditions, so as to improve the efficiency of the road network.

Keywords – network planning, primary roads with small spacing, traffic organization, traffic simulation

1. Introduction

Planners often set the primary roads system based on the suggested primary roads spacing. China registered planner qualification exam reference book advice: trunk road 700 ~ 1200 meters, and secondary roads 350~500 meters [10]; the fourth edition of "City Planning Principle" suggests that "Generally, appropriate channel spacing is considered 600 ~ 1000 meters" [16]. The above data has a profound impact on China's urban road network planning. Some planners traffic organization knowledge and ability is insufficient, so in the face of road network spacing lower than the recommended roads spacing caused by the terrain and other factors, they often use the method of separate processing or merging the road network; under the premise of controlling road network density according to the recommended primary road spacing, when the traffic load is heavy, use the processing mode of primary roads widening. However, "City Road Traffic Planning Design" (GB50220 - 95) 7.2.2 pointed out that "the city road network form and layout should determine it with considering the local conditions, based on land use, passenger and freight traffic source and distribution point, and traffic flow, and combined with the terrain, surface features, river direction, railway layout and the original road system [13], which means that the road network spacing control should be combined with the actual situation and flexibly processing. The developed countries have experienced a long time of motor development process, with a large number of road network cases, which can provide reference for the flexible processing of road network planning. There is a one-way road with small spacing and primary roads with small spacing these two kinds existing in the foreign road network system. The distance between the two parallel roads of primary roads with small spacing is only 80 to 150 meters. Analyzing its traffic flow line, and making microscopic traffic simulation to analyze the traffic operation of this type of road network model, can provide reference for China's road network planning.

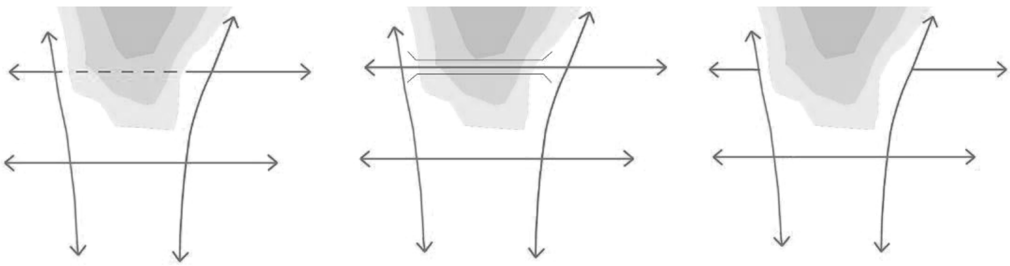
2. Comparison of road network planning modes under specific circumstances

2.1. General methods in China

In network planning, it will often encounter factors of topography, river and so on influencing the setting of network. Take the mountain barriers as an example (as shown in Figure 1). In order to meet the recommended roads space, road planning needs to pass through the mountain. There are two kinds of practices in the case, one is that the planning road directly passes through the mountain roads (including to pass through the obstacle in the case of other factors) method to be in accordance with conventional road spacing requirements (Figure 1-b); the second is to separate the roads and to connect with the other roads (Figure 1-c). The method of constructing the tunnel is too high in cost; the method of separating the road network needs to widen and make the canal processing the incorporated roads.

However, in practice, planners lack the awareness widening and tunnel processing of the roads, and the separated road may cause traffic congestion problems. For example, Xiangyang Road located near the Suzhou Hengshan Park is separated because of the Hengshan barrier and accessed to Su Fu Road by bluestone road. But the accessed road without channelization or widening process, it leads to intersection of bluestone road and Su Fu Road and Su Fu Road have traffic congestion problems (as shown in Figure 2).

There are many ways to deal with the road network with heavy traffic pressure. The widening of the road, as the simplest method, is often used by Chinese planners. Li [4] and Qian [8] considered that to increase the density of road network can ease traffic pressure, high road network density can reduce the proportion of each intersection turning left and the intersection scale, increase the average lane capacity, thereby increasing the road network capacity. The Potuzak [6] through the setting research on primary road - access road plane suggested that, by reasonable timing and tunnel processing of primary road - access road cross-shaped intersection, it can improve road network density and capacity by increasing crossing access road in the case of not influencing the traffic capacity and speed.



(a) The planned roads to cross mountains

(b) The tunnel connecting roads

(c) Separated road network bypass the mountain

Fig. 1 - Conventional road network choice in terrain, river, and other factors

(a) Road network separated (b) Google viewing of congested road

Fig. 2 - Primary roads separation case of Heng Shan Park in Suzhou

2.2. Foreign special methods

There are many special cases in the road network system of the mechanization-developed countries. In the case of terrain, river and other factors affecting the road network settings, take some non-conventional road network organization mode [5,7,11,16]. Take Berlin as an example (as shown in Figure 3), the distance from primary road A to Spree is only 340m. Due to the limit of Spree north river and south settlements, primary road B is set in a zigzag along the river channel, with distance to primary road A of 70 to 240m, and the spacing between the two primary roads is much smaller than Chinese proposed road spacing. From the whole network system in the area, the setting of primary roads A and B has its rationality and necessity: primary road A, as an important road for the area to city center and the central rail station, meets the main commuter demand within the area, and shares the traffic pressure of primary road D; the main function of primary road B is to connect the residential area with the school, and to meet the residents travel demand. According to the conventional method in China, the way of road separating and then combining to meet the proposed road spacing, may cause heavy traffic pressure in the area and lead to traffic jams [1,2,9,12].

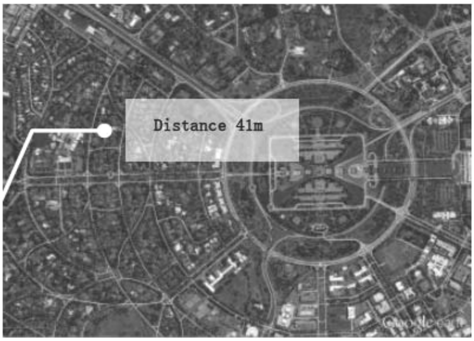
In heavy traffic pressure area in foreign cases, there are two ways of one-way roads with small spacing and primary roads with small spacing to improve the traffic capacity of road network, such as Canberra one-way roads with spacing of 41m and Berlin one-way roads with spacing of 88m traffic organization; Losangeles primary roads with spacing of 51m and Nagoya primary roads with spacing of 120m traffic organization (as shown in Figure 4).

(a) Local road network organization (b) Regional road network organization

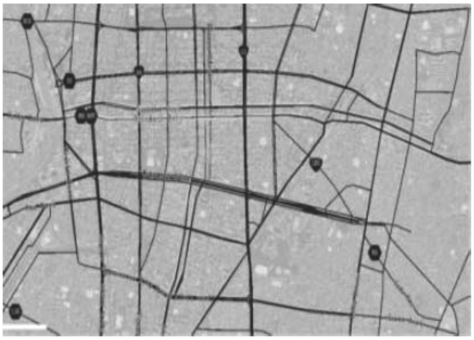
Fig. 3 - German case of primary roads with small spacing

(a) Los Angeles primary roads
with small spacing (1)

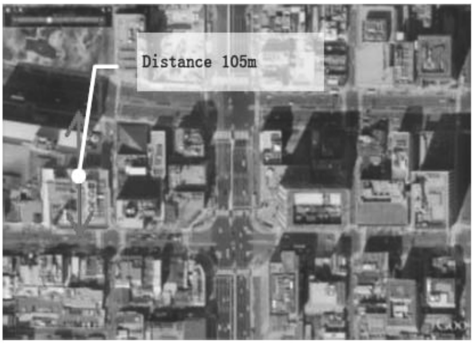
(b) Los Angeles primary roads
with small spacing (2)



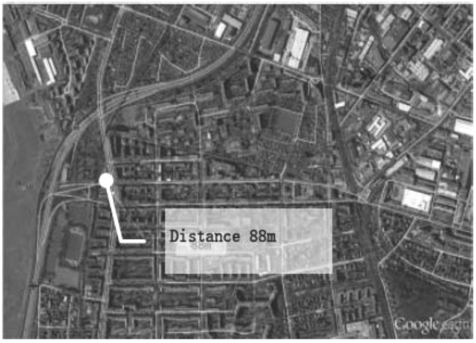
(c) Canberra primary roads with small spacing



(d) Nagoya primary roads with small spacing (1)



(e) Nagoya primary roads with small spacing (2)



(f) Berlin primary roads with small spacing

Fig. 4 - Foreign one-way roads with small spacing and primary roads
with small spacing combination cases

Through the above cases, it can be seen that, in dealing with the corresponding problems, there is a special network organization mode in China different from foreign road network, namely the small spacing primary roads.

The one-way roads traffic organization with small spacing is easy to understand, while the research on primary roads with small spacing is remained to start.

3. Traffic organization and simulation analysis of primary roads with small spacing

3.1. Traffic organization analysis of primary roads with small spacing

The research on the primary roads - access roads cross-shaped intersection takes the primary roads - access roads intersection and primary roads - primary roads - intersection as the intersection combination, and uses traffic simulation and running efficiency comparison to make analysis [3,14,15]. Primary roads with small spacing can learn from the above method to analyze, regarding the primary roads with small spacing as a combination intersection.

In Figure 5, the primary roads with small spacing (A and B roads near the primary roads), set the center line distance $L_{center\ line}$ between the primary roads.

The intersection traffic organization is shown in Figure 6, using the four-phase signal control mode. In order to facilitate the analysis, the direction of the map is determined to be North on the top and South in the bottom.

In the first phase, it is simultaneous release in the straight line from east to west and west to east; the turning left vehicles from east to south and west to north waiting in the waiting area.

In the second phase, the turning left vehicles from east to south and west to north are released, in which the turning left vehicles from east to south on the road A, and the turning left and vehicles from west to north, after released, wait in the area of north - south primary road. North -south waiting area H2 on the south - north primary roads needs to meet the driving space requirement Sl of the west - south turning right vehicles and east - south turning left vehicles on the road A. South - north waiting for driving area H1 on the south - north primary roads needs to meet the driving space need S2 of west - north turning left vehicles and east - north turning right vehicles on the road B. In consequence, it requires the coordination between the length of $L_{center\ line}$ and S1, S2, traffic signal period and light time. This is the key to rational organization of such junctions. If the length of the waiting for driving areas H1 and H2 reaches 100m (primary road centerline distance of about 150m), then can place 24pcu vehicles. The signal cycle is considered as 120 seconds, primary roads lane traffic demand is considered as 800pcu, primary roads are considered as the two lanes, the total entrance flow is 1600pcu/h, and the average cycle is 54pcu. Then the allowed turning left and turning right ratio is 24/54=44%. If the length of the waiting for driving areas H1 and H2 is 60m (primary road center line distance of about 100m), then can place 14pcu vehicles, then the allowed turning left and turning right ratio is 14/54=26%.

The third phase, south - north, north - south straight vehicles are released, north - east turning left and south - west turning left vehicles wait in the waiting area.

The fourth phase is the release of north - east turning left and south - west turning left vehicles.

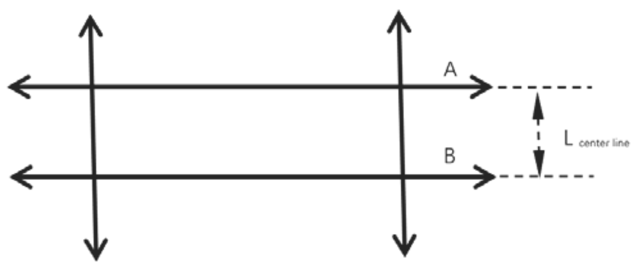
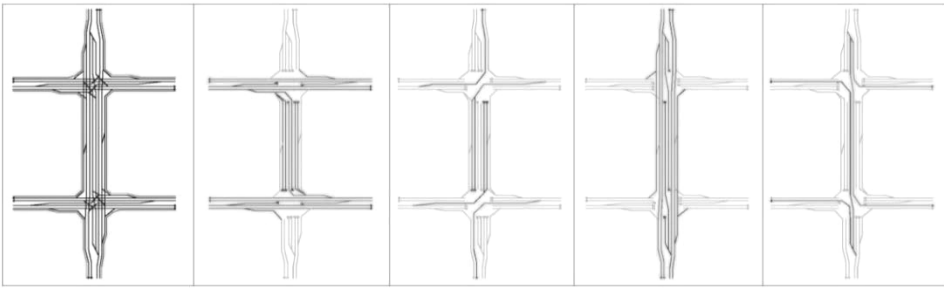


Fig. 5 - Road network mode of primary roads with small spacing



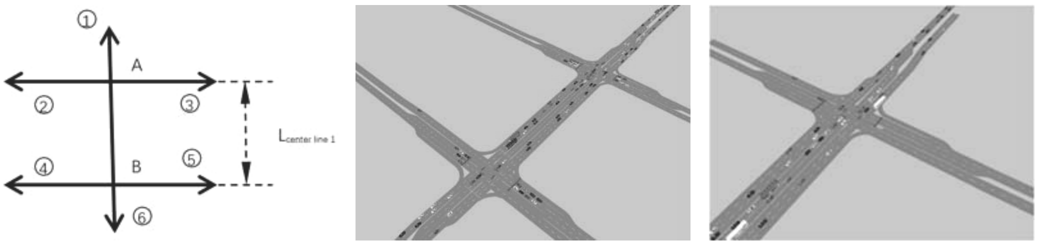
(a) Intersection flow line (b) One-phase (c) Two-phase (d) Three-phase (e) Four-phase

Fig. 6 - Traffic organization of intersection of primary roads with small spacing

3.2. Small spacing road simulation

Carry out traffic simulation of primary roads with small spacing, test the traffic capacity, and simulate the traffic flow analysed in the previous part. In the simulation of primary roads with small spacing, two east-west primary roads and north-south primary roads are two-way 4 lanes. Two primary road -primary road intersections set the left turn lanes and left turn waiting zone, and the distance L_{center} line 1 between the two east-west roads is 130m, far less than the suggested primary roads spacing (as shown in Figure 7). The ratio of the passenger car to the car is 1:9, and the entrance left, straight, and right traffic ratio are set by 10%, 80%, 10%, in accordance with the analysed left and right ratio allowance value, the signal cycle of 100 s. Since that there are few vehicles in the continuous turning primary roads with small spacing, it is not considered in the traffic simulation. Two adjacent primary roads use the same signal timing, and the signal timing is shown in Table 1.

According to the green time, set the primary roads entrance traffic volume of 1450 vehicles·h-1. Make use of the "timer" in VISSIM software to make a statistic of the traffic and average traffic time of vehicles passing through a road from the starting point to the finishing point in a period of time, so the set OD traffic can be compared with the simulated OD traffic in simulation of the primary roads network with small spacing. In the entrance section of each lane, set the timer starting point in the vehicle release control with distance of 600m to the intersection; exclude continuous turnings, and driving track with small traffic; in each lane exit section, set the timer finishing point in the place where has a distance of 600m from the intersection. Set in the period of 0 ~ 2800s, 3600 ~ 6400s, and 7200 ~ 10000s, vehicles are being driven, the test time is 600 ~ 10800s, and the time interval is 1800s, then obtain the traffic in the period of 600 ~ 2400s, 4200 ~ 6000s, and 7800 ~ 9600s.



(a) Intersection (b) Combination simulation of primary roads with small spacing (c) Single intersection simulation

Fig. 7 - Traffic organization of intersection of primary roads with small spacing

Lane entrance and exit labels are shown in Figure 7 a), the set OD traffic is shown in Table 2, and the simulated OD traffic is shown in Table 3 (the simulated OD traffic takes the three times average, unit for the vehicle·h-1). Compare Table 2 and Table 3, it can be seen that, the set OD traffic and the simulated OD traffic is basically the same, the ratio of 0.987, which suggests that the traffic flow line simulation analyzed in the previous part runs well.

Tab. 1 - Small spacing primary roads signal timing

Intersection name	Entrance and direction		Signal timing		
			Starting time of green	Finishing time of green light	Yellow light
		Turn left	39	49	
		Go straight	0	35	
		Turn left	39	49	
		Go straight	0	35	
		Turn left	89	99	
		Go straight	50	85	
		Turn left	89	99	
		Go straight	50	85	
		Turn left	39	49	
		Go straight	0	35	
		Turn left	39	49	
		Go straight	0	35	
		Turn left	89	99	
		Go straight	50	85	
		Turn left	89	99	
		Go straight	50	85	

Tab. 2 - Small spacing primary roads set OD traffic

Starting point	Finishing point					
	1	2	3	4	5	6
	0	145	145	145	145	870
2	145	0	1160	0	0	145
3	145	1160	0	0	0	145
4	145	0	0	0	1160	145
5	145	0	0	1160	0	145
6	870	145	145	145	145	0

Tab. 3 - Simulated OD traffic of primary roads with small spacing

Starting point	Finishing point					
	1	2	3	4	5	6
	0	148	152	164	149	862
2	139	0	1145	0	0	143
3	142	1157	0	0	0	146
4	151	0	0	0	1150	151
5	147	0	0	1134	0	144
6	895	145	157	145	146	0

3.3. Small spacing road network simulation

According to the small spacing road simulation model, construct small spacing road network simulation model, to simulate the operation of small spacing road in the road network (as shown in Figure 8). The distance $L_{center\ line}$ 1 between the roads in the east and west is 130m, and the distance between the centre point of the primary roads with small spacing $L_{center\ line}$ 2 is 600m. The two roads use signal coordination control, in which the timing of C and D intersection signal is the same as that of small spacing road simulation model A and B intersection; the timing of E and F intersection signal has half cycle difference compared with that of C and D intersection signal. Lane import and export label is shown in Figure 8 (a). Taking the setting mode of small spacing road simulation model timer as an example, use the same method to set the small spacing road network timer, set 0 ~ 2800s, 3600 ~ 6400s, 7200 ~ 10000s these three-time period for vehicle driving, and the test time is 600～10800s, time interval is 1800s, then obtain the traffic of the three-time periods 600～2400s, 4200～6000s, and 7800～9600s. By comparison, it is found that the setting of OD traffic is basically consistent with the simulation OD traffic, with ratio of 1.0057. It can be seen that the small spacing roads can also operate well in the road network.

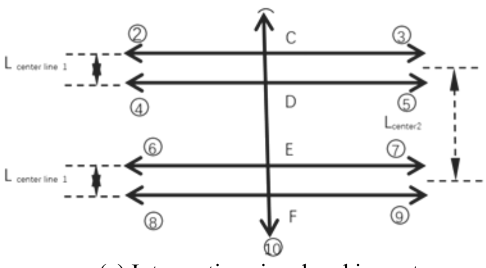
4. Advantages of primary roads with small spacing

4.1. Flexible road network organization

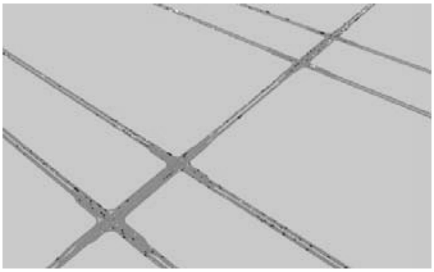
When meeting with the topography, rivers, land and so on factors influencing the network settings, primary roads with small spacing can better deal with the corresponding problems. The mountain obstacles factor is taken as example (as shown in Figure 9). Primary roads with small spacing setting can avoid traffic congestion problem brought about by conventional separated road network. The setting mode of primary roads with small spacing provides planners with new ideas for the road network planning, and facing the network layout problems that cannot be solved by conventional method, the form of a more flexible network can be taken.

4.2. Advantages of primary roads with small spacing

The setting of primary roads with small spacing, compared with the conventional network road setting mode, is more conducive to the land development and public transport development. The two-way road, compared with one-way road, has more frontages and higher accessibility. In the city center or business intensive areas, primary roads with small spacing can form better agglomeration effect and business environment, and promote the development of nearby plots. Moreover, primary roads with small spacing can set up bus lane road in the two lines, which is conducive to slow traffic development, and it can alleviate the traffic pressure.

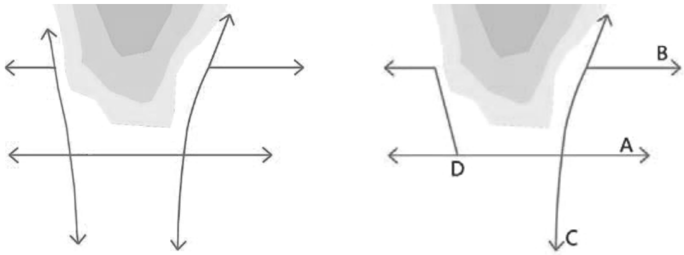


(a) Intersection signal and import and export labeling



(b) Small spacing two-way road network simulation

Fig. 8 - Traffic simulation of primary roads with small spacing



(a) Conventional separated road network

(b) Small spacing road network processing method

Fig. 9 - Road network processing method of small spacing under mountain block

5. Conclusions

Through the study of foreign related cases, when the network does not meet the normal spacing requirements or traffic pressure is large, primary roads with small spacing, compared with conventional road network settings, can better deal with the corresponding problems. In addition, it has the advantages of flexible network organization, beneficial for land development and public traffic development. Network planning is a complex issue, which cannot be solved by simply using the conventional treatment methods. In the arrangement of network road, planners should combine with the actual situation, profoundly study and prepare local road network planning so as to improve the efficiency of road network.

Acknowledgement

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Research on the calculation of coverage rate of bus stop based on GIS

J. Wang J.J. Yan

Institute of transportation engineering, Changsha University of Science & Technology
Changsha 410076, Changsha, China

Abstract

Urban public transportation has several advantages, including intensiveness, high-efficiency, energy-saving and environmental-friendliness. Giving development priority to public transportation is a necessary requirement in reducing traffic jams, transforming development mode of urban transportation and improving the life quality of people. And improving the coverage rate of bus stop is an important mean to prioritize public transportation development. The coverage rate of bus stop is an important index to evaluate the level of bus services. Under the consideration of deficiencies of calculating the coverage rate with traditional methods, including the great difficulty to acquire the information of bus stops, the low efficiency in deducting repeated area and the inaccuracy of calculation results, an idea of calculating the coverage rate of bus stop with GIS buffer tool and isochrones tool is put forward in this paper. In addition, case study is done in this paper to prove the powerful operability of the two tools, which provides good technical supports for urban public service.

Keywords – public transportation, coverage rate of bus stop, GIS, big data, buffer tool, isochrones tool

1. Introduction

With the rapid development of urbanization, motorization process has been accelerated, and a lot of cities encounter many problems, such as more congested traffic and increasingly serious environmental pollution, which continuously lowers the quality of people's life. Practice has proved that giving development priority to public transportation is an effective way to reduce traffic jams and improve the quality of people’s life. The urban public transportation has several advantages, including intensiveness, high-efficiency, energy-saving and environmental-friendliness. Giving development priority to the public transportation and constructing “Transit Metropolis” are necessary for sustainable development of urban transportation. In recent years, the development of public transportation has been accelerated in many cities by compiling traffic plans, investing a lot of money and formulating many supporting policies. It is expected to improve the level of public transportation services through these measures. The coverage rate of bus stop is an important index to evaluate the level of public transportation services [3]. In this index, it is required to achieve the goal that the coverage rate within a region with a serving radius of 500 meters in urban built-up regions is over 90%, so that people can reach the bus stop within 500 meters and transfer a bus within 5 minutes [4, 7, 10].

The accuracy of the index has a direct impact on the objectivity of evaluation, and how to improve the accuracy has always been a hot issue in the field of public transportation. The coverage rate of bus stop in early phase is calculated by calculating the coverage area of each stop through CAD, adding up those areas and deducting the overlapping portion between two neighboring bus stops based on the definition of the index. Because it is required to deal with the data of bus stops one by one, the calculating process is relatively complex [2]. With the extensively application of TransCAD in transportation industry, it is relatively convenient to calculate the coverage rate of the bus stop. With this method, the data of bus stops can be dealt with in batch, but it is still unable to deduct the overlapping area conveniently [6].

On the whole, in regard to the calculation of the coverage rate of the bus stop, there are some deficiencies in the traditional method above-mentioned, such as the difficulty to acquire information, the low efficiency of deducting the overlapping area and the inaccuracy of calculation results [8-9, 12]. In recent years, the Internet technology, GPS and others develop rapidly, which provides great technological means for the precision of calculating the coverage rate. Therefore, the idea of calculating corresponding coverage rate of bus stop with Geographic Information System (GIS) and the open Internet platform is proposed in this paper.

2. Improvement of calculation method

2.1. Definition of the coverage rate of bus stop

The coverage rate of bus stop is defined as the ratio of the covered serving area of a bus stop to the area of urban built-up regions, and it is calculated as follows [13]

$$f = \frac{\sum_{i=1}^{n} a_i}{A} \tag{1}$$

where, "i" represents a bus stop, "n" represents the number of bus stops; "a_i"represents the covered serving area of a bus stop, which is generally defined as the area covered by a circle with radius of 300 meter or 500 meter; "A" represents the area of urban built-up regions. The higher the ratio is, the larger the serving area of bus stops is.

2.2. New idea of calculating the coverage rate of bus stop

The calculation principle of the coverage rate of bus stop is relatively simple, which can be come done to summation of areas of many added circles. But in practical calculation, it is cumbersome to collect location information of bus stops that is required. One reason is the large number of bus stops, and another is the difficulty to accurately gain location. Therefore, the combination of GIS and open Internet platform is proposed to accurately gain the location of each bus stop in this paper.

Currently, the Internet provides many network maps, such as Amap, Baidu map and Tencent map, etc. A large number of Geographic information data have been provided by them, including the name, attribute and coordinate of a stop, a house, a shop, and so on. Some of these network maps have been set with open Internet platforms, which provide a function of acquiring the information of bus stops in a batch mode for researchers freely. The information can be imported into the GIS, and be used to calculate the coverage rate of bus stops quickly.

GIS is a technological system of collecting, storing, managing, calculating, analyzing, demonstrating and describing geographic distribution of data in the whole earth surface. It is equipped with powerful functions, such as map making, large quantity space data management, spatial analysis, integration, spreading as well as sharing of geospatial information. Urban construction land can be selected out with ArcMap10.2 of GIS by analyzing the characteristics of POI density and people's activity [9-10], which eliminates the error caused by manual measurement and calculation. With ArcMap10.2 of GIS, all kinds of data acquired by catching technology can be visualized to view the spatial distribution clearly; meanwhile, the tool within the GIS can be used to generate the covering area of bus stops without overlapping part quickly.

3. Method of utilizing GIS buffer tool

3.1. Thoughts of calculation

Main ideas: first, use the data-catching tool to find the information concerning the locations of all bus stops within the survey region; second, import the information of all the bus stops into GIS, from which we can see the spatial distribution; third, utilize the buffer tool to generate the covering area of bus stops; fourth, acquire the built-up area by identifying the urban construction lands with POI [5, 11]; finally, calculate the coverage rate of bus stops within the survey region based on the definition.

3.2. Operation steps

3.2.1. Catch of the data of bus stops

POI is the point of interest. A POI can be a house, a shop, a bus stop, etc. different types of POI can be acquired with the crawling technology within a short time. GeoSharp1.0 is novel development software which has many functions, for instance, geocoding, administrative divisions and POI collecting as well as coordinated transformation. A lot of POIs can be acquired quickly with the GeoSharp1.0.

The process of catching POI date of bus stops: open the Amap,, set the POI type as normal bus stop with the data catching tool—GeoSharp1.0 (see Figure1 for details), input the longitude and latitude information to determine the scope and acquire the location distribution information of all bus stops, and then input the caught information into GIS to acquire specific location distribution (see Figure 2 for details).

3.2.2. Calculation of coverage rate of bus stop

With ArcMap10.2, set the bus stop as circle center, input the serving radius value of bus stops with buffer tool (see Figure 3 for details), select "ALL" as the integration type and then acquire the covering area without overlapping parts (see Figure 4 for details).

Fig.1 - The tool window of the GeoSharp1.0