https://doi.org/10.58195/iaet.v1i1.001

Global Science Publishing

IAET

Innovations in Applied Engineering and Technology

https://ojs.sgsci.org/journals/iaet

Article

Evaluation and Improvement of Carrying Capacity of a Traffic System

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Abstract: This paper proposes indicators to evaluate the operating conditions of the traffic system. Through the evaluation, find the key problem nodes in traffic system and apply specific improvement measures to improve them. For evaluation of traffic capacity, use "3 steps method" to forecast the traffic volume in the traffic system which means based on current data multiply the nature increase coefficient to forecast the nature increase of the traffic volume, then add the new traffic volume created by new buildings to get the total traffic volume in future. Then, use specific indicators to evaluate the traffic conditions and find bottlenecks in the traffic system. After that, improve the capacity of the traffic system by improve the capacity of bottlenecks. Finally, evaluate the traffic condition again and test the improvement effect by comparison.

Keywords: traffic systems; bottlenecks; evaluation; improvement measures

1. Introduction

With the rapid development of city, there will be more and more buildings, people and vehicles in traffic systems. Large traffic demand leads traffic capacity challenges to traffic systems. In specific, at an intersection, if the traffic volume exceeds the capacity which means there are too many vehicles, there will be jams [1–4].

In this paper, a typical region was chosen to research. The research region is located in Nanshan Overseas Chinese Town area of Nanshan District, Shenzhen, which is surrounded by Shahe east road, Xiangshan west street, Shahe street and Xinzhong road (shown in Figures 1 and 2).

Figure 1. Location of research region.

Received: 1 September 2022; Accepted: 17 October 2022.

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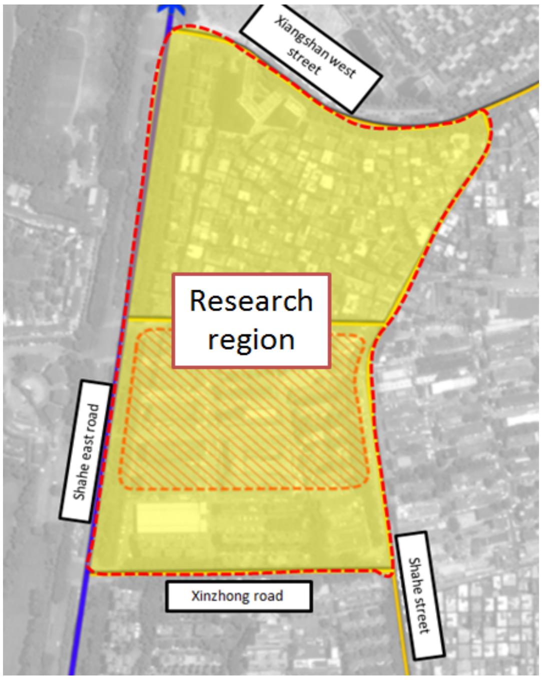

Figure 2. Boundary of research region.

The reason to choose this region is it located in Nanshan district which is a well-developed area and the traffic problems there are more typical than some remote areas. At the same time, there will be new buildings in research region which means the traffic system will face new challenges (shown in Figure 3). Therefore, in this research, if the traffic problems can be solved, the recommendations and measures used in this region can also be referenced to other traffic systems [5–7].

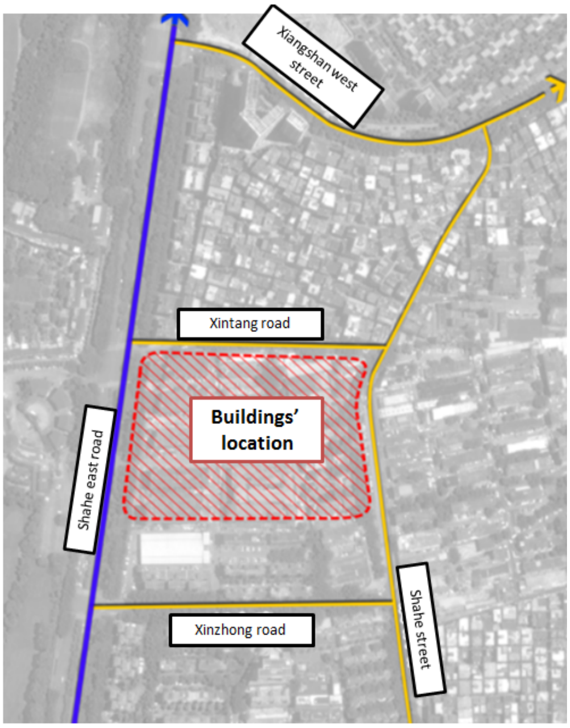

Figure 3. New buildings' location.

2. Methodology

Due to operability and cost reason, this research focus on evaluate and improve some certain bottlenecks in this traffic system to improve the total condition of the system [8–13] (shown in Figure 4).

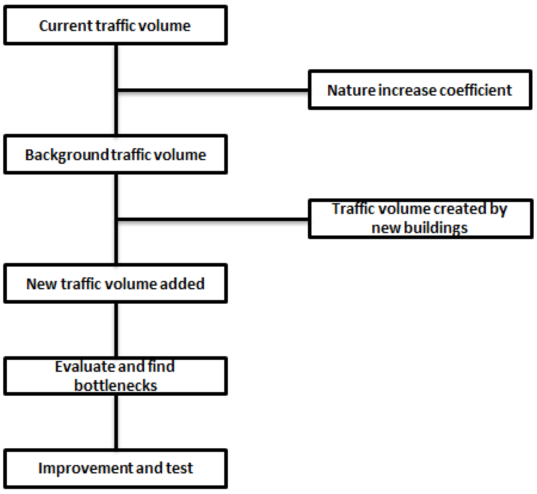

Figure 4. Framework of capacity evaluation and improvement.

Current traffic volume comes from investigation which includes the number of vehicles of each turning at intersections. Nature increase coefficient can be calculated by historical data comparison. And use this coefficient to multiply current traffic volume to get background traffic volume which means the traffic volume in future due to nature increase. Then add the traffic volume created by new buildings to background traffic volume to get new traffic volume added in future. After that, calculate the saturations and service level of each turning to found bottlenecks. Finally, apply specific measures to improve the capacity of those bottlenecks and test the effect by comparison [14–18].

The method to calculate the traffic volume created by new buildings is showed below (shown in Figure 5).

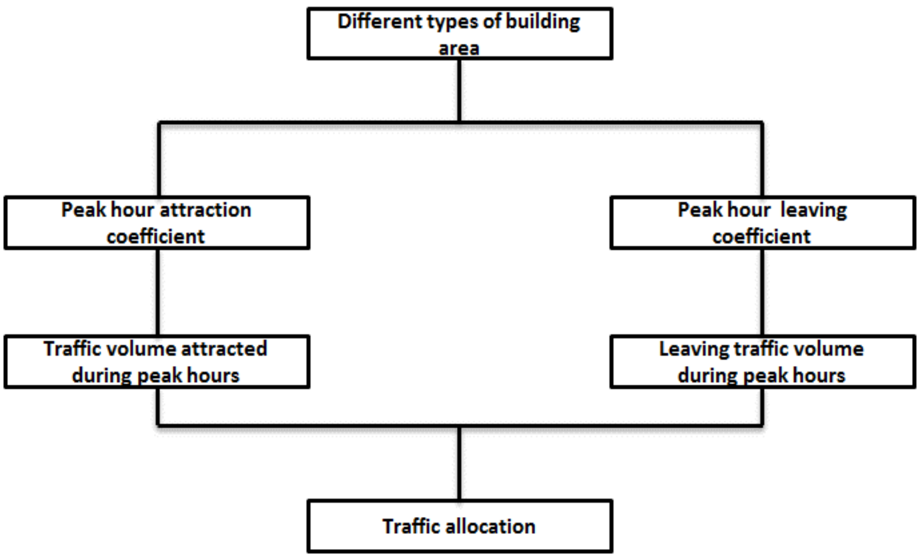

Figure 5. Calculation of traffic volume created by new buildings.

Use building area to multiply the attraction or leaving coefficient to get the number of people coming or leaving of the building. Then translate the number of people to number of standard cars. Finally allocate the new traffic volume to specific roads and intersections combine with specific network.

The way to judge the traffic condition is using "service level" to evaluate. And determine levels by calculating saturation [1].

Table 1. Corresponding relationship between saturation and service level.

Service level	Saturation	Note
A	≤0.25	Free traffic flow

Cont.

Service level	Saturation	Note
B	0.25< saturation≤0.5	Nearly free traffic flow
C	0.5< saturation≤0.7	Smooth traffic flow
D	0.7< saturation≤0.85	Relatively smooth traffic flow
E	0.85< saturation≤0.95	Lightly jam
F	0.95< saturation	Jam

According to the Table 1, “A, B, C” levels are good conditions; “D” is can be acceptable, “E, F” are relatively bad conditions which mean there are jams. The rules to find bottlenecks in this system are:

(1) When new traffic volume added, if the service levels of some turnings become worse, those are bottlenecks in this system and need to be improved. Details as follows:

If the service level change from

a) “A, B, C” to “D, E, F”,

b) “D” to “E, F”,

c) “E” to “F”,

d) “F” to “F” (the saturation become higher),

Note: “A” change to “B” or “C” is not become worse because they are all good conditions.

(2) If new traffic volume added and the service levels of some turnings are worse than “D”, they are the bottlenecks in this system.

3. Evaluation and Find Bottlenecks

In traffic industry, saturation of a certain turning =Traffic volume of this turning / (the number of lanes in this turning * each lane’s capacity) *(green light duration / signal cycle). Combine with fundamental investigation data, the saturation of each turning can be calculated and the corresponding service level can be determined [19].

Table 2. Saturation and service level in 2021 (before improvement).

-	-	-	-	-	-	-	Background			Total (new traffic volume added)			
Name	Approach direction	Turning	Number of lanes	Capacity of each lane (pcu/h)	Signal cycle(s)	Green light duration(s)	Traffic volume (pcu/h)	Saturation	Service level	New traffic volume (pcu/h)	Traffic volume (pcu/h)	Saturation	Service level
1. Shahe Rd - Xinzhong Rd	E	Left	0.5	1500	106	41	117	0.40	B	42	159	0.55	C
		Right	0.5	1550	106	106	97	0.13	A		97	0.13	A
	S	Direct	3.5	1650	106	35	1879	0.99	F	155	2035	1.07	F
		Right	0.5	1550	106	106	175	0.23	A	311	486	0.63	C
	N	Left	1	1500	106	30	227	0.53	C		227	0.53	C
		Direct	4	1650	106	65	1102	0.27	B		1102	0.27	B
2. Shahe Rd - Xintang Rd	E	Left	0.5	1500	106	32	19	0.09	A	253	272	1.20	F
		Right	0.5	1550	106	106	117	0.15	A	21	138	0.18	A
	S	Direct	3.5	1650	106	41	2074	0.93	E		2074	0.93	E

Cont.

-	-	-	-	-	-	-	Background			Total (new traffic volume added)			
		Right	0.5	1550	106	106	19	0.03	A		19	0.03	A
	N	Left	1	1500	106	33	162	0.35	B	233	395	0.85	D
		Direct	4	1650	106	75	1484	0.32	B		1484	0.32	B
	E	Left	1	1500	106	32	298	0.66	C		298	0.66	C
		Right	1	1550	106	106	104	0.07	A		104	0.07	A
3. Shahe Rd - Xiangshan W St	S	Direct	4	1650	106	41	1607	0.63	C	105	1712	0.67	C
		Right	1	1550	106	106	298	0.19	A		298	0.19	A
	N	Left	1	1500	106	33	389	0.83	D		389	0.83	D
		Direct	4	1650	106	75	1166	0.25	A	233	1400	0.30	B

Considering the service level comparison, there are 4 bottlenecks in this traffic system:

(1) The south approach direction's direct turning of intersection 1 (Shahe Rd - Xinzhong Rd) (shown in Figure 6).

(2) The east approach direction's left turning of intersection 2 (Shahe Rd - Xintang Rd).

(3) The south approach direction's direct turning of intersection 2 (Shahe Rd - Xintang Rd).

(4) The north approach direction's left turning of intersection 2 (Shahe Rd - Xintang Rd).

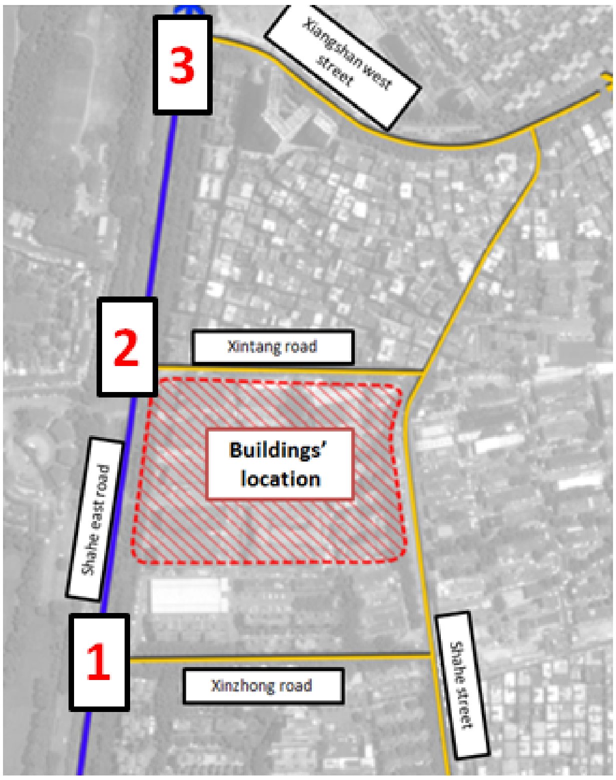

Figure 6. Location of intersections.

4. Improvement measures

4.1. Improvement of intersection 1 (Shahe Rd - Xinzhong Rd)

For intersection 1 (Shahe Rd - Xinzhong Rd), south approach direction's direct turning needs to be improved. As evaluated in Table 2, the service level of this turning in background condition has been “F” already and become worse in new traffic volume added condition (saturation become higher). Briefly, according to forecast and evaluation, this turning will be very congested in 2021 and it need to be improved [20–22].

Analysis: Currently, in the south approach direction, there are 3.5 direct lanes and the width of each lane is 3 meters. According to the topographic maps, the width of green belt in this approach is 6 meters, thus it is enough to add 1 lane for direct turning.

Recommendation (shown in Figure 7): Reduce the width of the green belt by 3 meters and add a direct lane. Change the lanes from 3.5direct +0.5right to 4.5direct +0.5right.

Note: The reasons why only add 1 direct lane are according to test, add 1 lane is enough to make service level of this turning can be acceptable (“D”) and for economy. The testing solution will be showed in comparison table.

Figure 7. Intersection 1 (Shahe Rd - Xinzhong Rd) improvement.

4.2. Improvement of intersection 2 (Shahe Rd - Xintang Rd)

For intersection 2 (Shahe Rd - Xintang Rd):

(1) East approach direction’s left turning needs to be improved. As evaluated in Table 2, when new traffic volume added the service level of this turning changed from “A” to “F”.

(2) South approach direction’s direct turning needs to be improved. As evaluated in Table 2, in 2021, the service level of this turning is “E” which means there will be lightly congestion.

(3) North approach direction’s left turning of needs to be improved. As evaluated in Table 2, when new traffic volume added the service level of this turning changed from “B” to “D”.

Analysis:

(1) Currently, there is only 1 vehicle lane in east approach. It is used both for left and right turnings. According to topographic maps, the width of this lane is 4.25 meters. In road design regulations and standards, this width can be reduced to 3 meters. But it is still not enough to add lanes for left turning. Thus, the width of east approach needs to be extended. Combine with topographic maps and facilities nearby, it can be widened by 3.5 meters.

(2) Currently, in the south approach direction, there are 3.5 direct lanes and the width of each lane is 3 meters. According to the topographic maps, the width of green belt in this approach is 6 meters, thus it is enough to add 1 lane for direct turning.

(3) For north approach, the capacity of left turning needs to be improved while the capacity of direct is sufficient. For economic reason, considering allocate some direct lanes’ space to the left turning.

Recommendation (shown in Figure 8):

(1) For east approach, extend the width of east approach road to the south by 3.5 meters; reduce the lane

width from 4.25 meters to 3 meters; increase lanes of left turning. (From 0.5 to 2)

(2) For south approach, reduce the width of the green belt by 3 meters and add a direct lane. Change the lanes from 3.5direct +0.5right to 4direct +1right.

(3) For north approach, change the lanes from 4direct +1left to 3direct +2left.

Note: The selection and determination of improvement measures and the testing of improvement effects are an interactive process. Based on the traffic conditions can be acceptable, trying to make minor changes.

Figure 8. Intersection 2 (Shahe Rd - Xintang Rd) improvement.

5. Improvement effect testing

According to comparison in the Table 3, after improvement, the service level of each turning is higher than "D". And the service level of each turning after improvement is not worse than background. Therefore, after improvement, the condition of this traffic system is acceptable and the improvement is effective. The capacity of the system has been improved.

Table 3. Comparison of before and after improvement.

-	-	-	Background		-	Total (before improvement)		After improvement	
Name	Approach direction	Turning	Saturation	Service level	New traffic volume (pcu/h	Saturation	Service level	Saturation	Service level
1. Shahe Rd - Xinzhong Rd	E	Left	0.40	B	42	0.55	C	0.55	C
		Right	0.13	A		0.13	A	0.13	A
	S	Direct	0.99	F	155	1.07	F	0.83	D
		Right	0.23	A	311	0.63	C	0.63	C
	N	Left	0.53	C		0.53	C	0.53	C
		Direct	0.27	B		0.27	B	0.27	B
2. Shahe Rd - Xintang Rd	E	Left	0.09	A	253	1.20	F	0.30	B
		Right	0.15	A	21	0.18	A	0.09	A
	S	Direct	0.93	E		0.93	E	0.81	D
		Right	0.03	A		0.03	A	0.01	A
	N	Left	0.35	B	233	0.85	D	0.42	B
		Direct	0.32	B		0.32	B	0.42	B
3. Shahe Rd - Xiangshan W St	E	Left	0.66	C		0.66	C	0.66	C
		Right	0.07	A		0.07	A	0.07	A

Cont.

-	-	-	Background		-	Total (before improvement)		After improvement	
	S	Direct	0.63	C	105	0.67	C	0.67	C
		Right	0.19	A		0.19	A	0.19	A
	N	Left	0.83	D		0.83	D	0.83	D
		Direct	0.25	A	233	0.30	B	0.30	B

6. Conclusion

The purpose of this research is to improvement the capacity of a traffic system. Different to traditional traffic studies, this research focus on a specific and relatively small region for analysis and try to discuss a complete set of evaluation and research methods. For capacity evaluation and improvement, based on current traffic data from investigation to forecast the background traffic volume in future. Then add the new traffic volume created by new buildings in this region to get the total traffic volume in future. After that, use specific indicators to evaluate the condition of the traffic volume and find bottlenecks in this traffic system. When bottlenecks are found, use specific measures to improved them and testing the effect by comparison.

Although this research has made some effort to establish a general evaluation theory to analyze the traffic problems in city and try to make the method could be copied to other areas, there are still many problems due to complex realistic traffic conditions. At the same time, because of the uncertainty of future prediction, in real life, the prediction and test results of this study need to be updated and adjusted in time.

Funding

Not applicable.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

Not applicable.

Conflicts of Interest

The author declares no conflict of interest.

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