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DESIGN AND SIMULATION ANALYSIS OF AT-GRADE INTERSECTION CHANNELIZATION OF CITY ROADS

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Original scientific paper
Urban road intersections are bottle-necks of urban road networks, and the traffic organization optimization of intersections is the crux to relieve urban traffic jam. After analysing the features, applicable conditions and functions of the intersection channelization design, the basic procedures based on traffic survey, channelization design of the intersections and assessment of channelization plan were finished. Then, the simulation model of the intersection was set up by VISSIM in consideration of problems at a large intersection in a city. Parameters comparison and simulation analysis show that proper measures of channelization at intersections can significantly improve their traffic capacity.

Keywords: *channelization design, case analysis, intersection, simulation, urban traffic*

Analiza projekta i simulacije kanaliziranja križanja u nivou na gradskim cestama

Izvorni znanstveni članak
Sjecišta gradskih cesta predstavljaju uska grla mreže gradskih prometnica te je optimalizacija organizacije prometa na križanjima ključna da se izbjegne zastoj prometa. Nakon što su se proanalizirale karakteristike, primjenjivi uvjeti i funkcije projekta kanaliziranja križanja, predloženi su osnovni postupci zasnovani na snimanju saobraćaja, projekt kanaliziranja križanja te procjena plana kanaliziranja. Zatim je izrađen model simulacije raskrižja pomoću VISSIM-a uzimajući u obzir probleme velikog križanja u gradu. Usporedba parametara i analiza simulacije pokazuju da odgovarajuće mjere kanaliziranja na raskrižjima mogu značajno pridonijeti poboljšanju kapaciteta prometa.

Ključne riječi: *analiza slučaja, gradski promet, križanje, projekt kanaliziranja, simulacija*

1 Introduction

With the rapid social and economic development in China, the total number of vehicles has been on the increase, so the increasing traffic volume imposes a significant challenge to the traffic capacity of the existing roads and traffic jam has been becoming more serious, especially at the intersections [1 ÷ 3]. Intersections are nodes of the urban road networks and also the throats for restricting traffic capacity, where the smoothness and safety are lower than regular roads due to mutual interruption of the motor vehicles, non-motor vehicles and passers-by [4 ÷ 7]. Therefore, how to help vehicles and passers-by safely and rapidly pass the intersections is the key to improve traffic capacity of urban intersections.

In some other countries, applicable standards and manuals have been established due to earlier initiation of study on channelization design of the intersection and more mature study systems. For example, Manual on Uniform Traffic Control Devices (MUTCD) of the United States introduces methods of channelization, sizes, colours and precautions of all facilities. Meanwhile, it has made so many studies on lane width, division of lane functions, and so on and proposed methods and principles for channelization design of the intersection [8]. Planning and Design of At-grade Intersections of Japan, with detailed discussion about channelization of the intersection, holds that channelization is very effective in settling the traffic jams [9]. Some other countries have also developed a wide range of traffic signal control systems and timing simulation software, e.g. SCOOT System of the U. K. and SCATS System of the Australia as well as VISSM, SYNCHRO, CROSIM and other simulation software. A series of integrated control experiments on the road intersections have been made by the Chinese scholars and the control method of "integrated mode" has been proposed with the "conflicting point string" that the traffic flow may be confronted with in passing the crossing as the unit based on the full consideration of the mutual conflicts among the traffic flow, which has mainly focused on seeking the coordination among channelization, phase and light colours. In combination with specific projects, Chinese scholars have proposed the measures for channelization traffic management within the range of intersection and discussed the applicable principles, technical requirements and applicable methods regarding channelization traffic. In 2001, Design Regulations for At-grade Intersections on Urban Street was published in Shanghai as an engineering construction code, which specified that the at-grade intersection should adopt traffic islands, pavement markings and traffic flow marks for channelization design [10]. These studies have significantly accelerated the development of urban traffic and constantly perfected traffic system in China. However, due to late initiation of study on traffic planning in China, without mature study system, it shall be further studied.

The channelization is targeted towards standardizing the running of the vehicles, reducing the interference among the traffic streams and protecting the passers-by and the motor vehicles in passing intersections [11 ÷ 13]. Based on the understanding of intersection channelization design theory, this paper, with a case study of a large-sized intersection, carried out the traffic survey, analyses the problems and proposes the solutions. Meanwhile, it optimizes the intersection channelization design with VISSIM simulation software to improve operation of the intersection.

The structure of the paper was organized as follows: First, the basic knowledge of the channelization design was introduced and then it was employed to a city

intersections canalized design. Parameters comparison and simulation analysis show the efficiency of the method.

2 Basic knowledge of channelization design

Channelization design is to guide the vehicles and passers-by to be on their proper way by setting traffic markings, signs and traffic islands so as to guarantee the traffic entities safely move along the specific direction and route in order without interference interruption and then realize the purpose of control and diverge the traffic flow [1, 12, 14, 15].

2.1 Features of channelization traffic

(1) Strong practicality. It can effectively shorten the distance between the vehicles and passers-by to pass the intersection and improve the traffic capacity and safety of the intersection.

(2) Excellent economical efficiency. It has small size, little investment, short construction period and good effect.

(3) High Safety. It can realize the traffic diverging from passers-by to the vehicles through the channelization traffic and guarantee proper right turn, straight going and left turn.

(4) Beautiful appearance. All kinds of flowers and plants can be planted on the channelization island so as to beautify urban environment and relieve the fatigue of the passer-by and the drivers as well. They also can play an important role in absorbing automobile exhaust.

(5) Strong integrity. All traffic facilities work together and are arranged harmoniously.

2.2 Applicable conditions of at-grade intersection channelization

(1)The channelization is applicable to the intersection with large traffic volume (including the one between the backbone roads and the one between the backbone road and the secondary main road) [3], and 4 lanes in double-way at least on the section of the crossing;

(2) The crossings of channelization traffic shall be broad with enough backing of buildings as well as large at-grade area and space for setting channelization islands and expanding motorways.

(3) Relatively higher proportion of vehicles turning left at the intersection. Within the range of the intersection, the distributing centre for the vehicles and the passers-by and the entrances shall be as less as possible and they shall be arranged beyond the intersection.

2.3 Functions of channelization traffic

(1) Increasing traffic capacity of the intersection and the traffic efficiency

Channelization will get rid of the conflicting points affecting the thoroughfare of passers-by and vehicles and weaken the mutual influences between the vehicles and the non-power-driven vehicle, in this way, the traffic capacity is improved and the traffic is smoother.

(2) Reducing traffic accidents

Due to both subjective and objective reasons, in case of mixed flow of vehicles, non-power-driven vehicles and passers-by on the road, the traffic participants behave randomly and some are weak in safety consciousness, leading to disordered traffic and potential traffic accidents [16, 17, 19, 20]. After channelization and traffic diverging of the vehicles, the non-power-driven vehicles and the passers-by, all of them are on their own way, eliminating the conflicting points, realizing the traffic diverging, clearly showing the way for the traffic behaviours and significantly reducing the traffic accidents and breach of regulations.

(3) Beautifying the urban environment

Since the intersection on urban streets is crowded with vehicles and passers-by, in order to create a beautiful city image, the intersection can be designed in such a manner that it looks beautiful. Besides effective channelization design, increase in traffic volume of the road and decrease in delay of the traffic stream at the intersection on urban streets, the greening and the landscape design of urban streets are also an important part of the design just because the landscape design can play a role in traffic guidance and control.

3 Case analysis

Based on the features, applicable conditions and functions of the intersection channelization design, the channelization design for an intersection in a city in Hebei Province, China is made with VISSIM simulation software in accordance with the intersection channelization design flow.

3.1 Intersection channelization design flow

The intersection channelization is a complex process and it shall be designed based on the traffic survey after analysing the traffic problems in the intersection in an all-round way and the reasons.

The intersection channelization design flow is shown in Fig. 1.

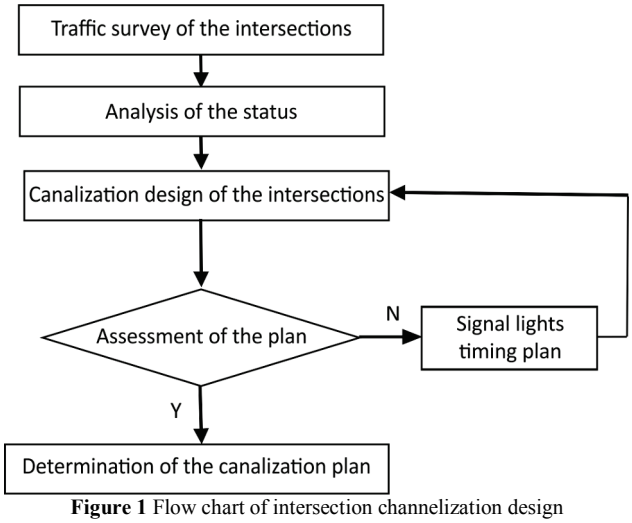

Figure 1 Flow chart of intersection channelization design

(1) Traffic survey of the intersections

Traffic survey is made to measure and analyse the road traffic flow and segments of relevant phenomena

with an objective method so as to understand and command the rules of traffic flow [15]. As the basis of channelization design, the traffic survey of the intersection mainly covers the survey of geometrical conditions, traffic conditions and signal timing of the intersection:

a) Survey of the geometrical conditions of the intersection, mainly including the survey of the location and nature of the intersection, lane width, number of lanes, width of separator and so on.

b) Survey of traffic conditions of the intersection, mainly including the survey traffic composition of the intersection, nature of the traffic flow, the peak hour traffic and so on.

c) Survey of timing scheme of the intersection, mainly including the survey of the signal cycle length, phase scheme and so on.

(2) Analysis on the status

Analysis of the current situation refers to the analysis of the traffic problems at the intersection in an all-round way based on the data gathered in traffic survey so as to analyse the main reasons for these problems.

(3) Channelization design of the intersections

It plans to propose the effective measures for settling the existing problems based on the analysis of the existing problems in the intersection and makes the channelization design of the intersection so as to improve the traffic capacity of the intersection and satisfy the demand of the passers-by under the precondition of guaranteeing the traffic safety [16]. The main design contents cover division of lane functions, geometrical design of entrance and exit roads and internal traffic organization of the intersection and so on.

(4) Assessment of channelization scheme

This paper mainly adopts queuing length, delay and service level of the intersection after channelization as evaluation indicators of the channelization scheme. The channelization scheme will be determined as design scheme in case of satisfying the design requirements. Otherwise, it is necessary to control the signal lamps in the intersection and then make the channelization design of the intersection again based on the signal timing scheme until the channelization scheme satisfies the design requirements.

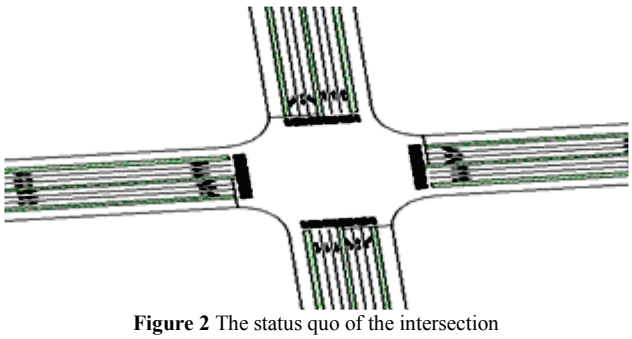

Figure 2 The status quo of the intersection

3.2 Description of current traffic conditions of the intersection

The intersection is confronted with heavy traffic pressure and large traffic flow. In addition, its design and traffic organization are not so reasonable, resulting in relatively great hidden danger. The current traffic conditions of the intersection are shown in Fig. 2.

3.3 Survey and analysis of current traffic conditions

3.3.1 Survey of current traffic conditions

Based on survey data of the current traffic conditions, the peak hour traffic at the intersection is obtained, shown in Tab. 1.

Table 1 Peak hour traffic

Direction	Traffic volume (*v*/*h*)			
	Turn left	Go straight	Turn right	Total
East entrance	198	1154	166	1518
West entrance	232	1137	163	1532
South entrance	228	1052	152	1432
North entrance	204	1026	158	1388

3.3.2 Analysis of existing problems

Through survey and study on the current traffic conditions of the intersection, it is found by this paper that the following main problems exist in the intersection:

(1) Heavy traffic pressure and fewer lanes at the intersection. This intersection is a typical cross intersection, located in the centre of a city, China. The bus station, marketplace and other places of easily attracting people-flow and vehicle-flow, were built around the intersection. So the intersection bore heavy traffic pressure, and the hidden danger was serious.

(2) Long queuing time of vehicles and low traffic efficiency. Queue was the important factor for the traffic system operation, which was significant input parameter of induced system of city traffic [21]. The traffic efficiency was seriously influenced by long queue time of vehicles at the intersections.

(3) Unreasonable signal control at the intersection. Traffic capacity of intersections was greatly related to signal timing. Traffic capacity and the safety of going and coming at intersections can be improved by reasonable signal timing design.

(4) Unreasonable division of lane functions. With traffic demand continuous growth, the phenomenon of traffic bottle-necks more highlighted. Lane function division was one of important links of intersection design. It had an influence on the assignment and distribution of space resources of intersections, which was the precondition of signal control design, to a great extent, affected traffic capacity of intersections.

3.4 Channelization scheme design

(1) Reasonably divide lane functions and add a through lane by narrowing the lanes and the separator.

(2) Arrange special phase for left turn and temporally separate the conflicting traffic flows within the intersection.

(3) Arrange channelization islands for the vehicles of turn right and effectively channel off traffic flows.

(4) Arrange turn waiting zone for left turn of the vehicles, reduce the waiting time of the drivers at the crossing and improve traffic capacity of the intersection.

(5) Stop line of vehicles and non-power-vehicles at the intersection move forward.

The channelization scheme design of the intersection is shown in Fig. 3.

3.5 Evaluation of channelization scheme

The intersection is the place for the vehicles from different directions to choose and change the route on the urban streets and the key distribution area of mixed traffic flow. This paper makes the channelization design of the intersection at question with VISSIM simulation software and evaluates the channelization scheme based on the average queuing length, delay and service level of the vehicles before and after channelization. The comparison of the evaluation parameters before and after channelization is shown in Tab. 2.

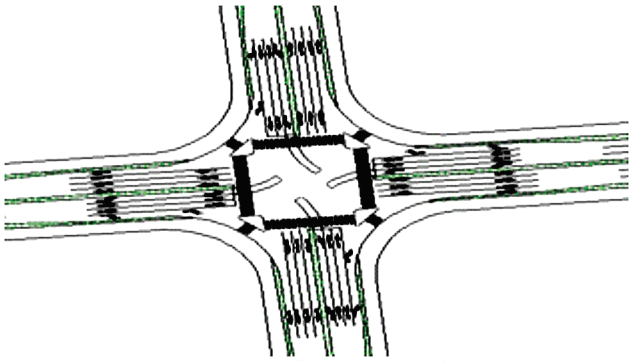

Figure 3 Channelization design scheme

In this paper, average queue length, average delay of vehicles and service level at the intersection, as comprehensive evaluation index, were compared before and after the channelization intersection. From Tab. 2, we can obtain the following information:

(1) Average queue length significantly decreased by optimization at the intersection. The average queue length of lanes in each approach declined from present 8,47 m, 13,07 m, 23,2 m, 23,7 m to 7,125 m, 8,8 m, 9,65 m, 9,125 m respectively. Due to the lane in each approach was added, the lane function division performs more reasonably and the stop lane of vehicles and non-motorized vehicles were moved forward.

(2) Average delay at the intersection was optimized from 21,1 s to 20,6 s, which was mainly because of the improvement and optimization of the traffic capacity of lanes in each direction. The average delay of east, south and west entrance increased, from 12,08 s, 29,28 s, 14,05 s to 19,16 s, 21,97 s, 20,04 s respectively. The average delay of north entrance significantly decreased, from 30,13 to 20,95 s.

(3) Level service of this intersection was still C, but the improvement of traffic capacity of this intersection after channelization design will not be changed. Intersection service level depends on the average delay of intersections. Average delay decreased from present 21,1 s to 20,6 s, and average queue length decreased significantly by channelization intersection. So, the traffic capacity will be improved at the intersection.

Finally, Tab. 2 shows that channelization design had significantly improved traffic capacity of this intersection, and the channelization plan was feasible and practicable.

4 Conclusion

It is advantageous to relieve the urban traffic jam through improving the traffic environment as well as traffic capacity and efficiency of the intersections on urban streets. After briefly introducing the intersection channelization, including the features, applicable conditions and purposes of the interaction channelization design, this paper proposed the specific flow of intersection channelization design and established a simulation model of intersection channelization design with VISSIM software in combination with a large-sized intersection in a city. It is shown by the channelization design results that the traffic capacity of the intersection and the average queuing length of the vehicles have been significantly improved, so the channelization design scheme is feasible and practicable.

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Table 2 Comparison table of parameters before and after channelization

Directions	Status Quo			Post-channelization		
	Average queue length / m	Average delay / s	Service level	Average queue length / m	Average delay / s	Service level
East	8,47	12,08	B	7,125	19,16	B
South	13,07	29,28	C	8,8	21,97	C
West	23,2	14,50	B	9,65	20,4	C
North	23,7	30,13	C	9,125	20,95	C
Intersection	17,1	21,1	C	8,7	20,6	C

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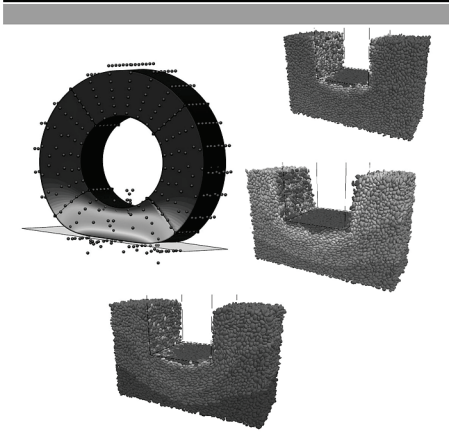

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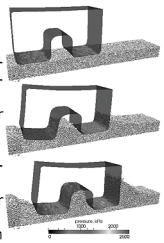

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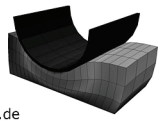

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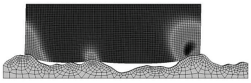

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