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Optimization of lane assignment for signalized T-intersection based on VISSIM

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Abstract: In order to improve the performance of the signalized intersection, an unconventional scheme tandem design (TD) is proposed. A simulation experiment is conducted to evaluate the capacity and delay under the unconventional scheme and two conventional lane assignment schemes. First, the VISSIM is employed as microsimulation to obtain the delay of different designs at signalized T-intersections under different conditions of traffic flow and turning proportion. Secondly, a method based on discriminant analysis (DA) is proposed to determine the best design scheme using the flow and turning proportion as inputs. Finally, a case study in Changsha city, China is used to demonstrate the efficiency and accuracy of these findings. The results indicate that the traffic flow and turning proportion are the crucial factors in scheme selection of lane assignment. Different from the previous research, the TD has better performance over various traffic flow levels. Furthermore, a proper proportion of left turns makes TD an outstanding option, which can reduce the delay and decrease the average number of stops and queue length significantly. However, the proportion should not be too high or too low. The research results can help practitioners obtain a quantitative view of appropriate design schemes at signalized intersections when trying to relieve traffic congestion according to different traffic conditions.

Key words: delay; T-intersection; tandem design; traffic flow; turning proportion
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The isolated signalized intersection is the bottleneck in road traffic networks[1]. It is a major source of delays for vehicular traffic. In order to improve the condition of traffic operations over the whole network, one fundamental task is to optimize the performance of isolated signalized intersections. Traffic signal control and lane assignment affect the performance to a great extent. The performance can be measured by delay and capacity, which are two most prevalent and crucial evaluation indicators. Tandem design (TD) is a special class of signalized intersections which is equipped with a mid-block pre-signal and its stop line in front of the main signal. The pre-signal alternates the allocation of green times to left-turning traffics (LT) and right-turning traffics (RT). By reorganizing the traffic flow in tandem, rather than leaving it side by side, as in the conventional design such as dedicated right-turn design (DRTD) and shared right-turn design (SRTD), the conflicts arising between vehicles as they approach the intersection are resolved, thus increasing the capacity of signalized intersection[2]. The remarkable results of pre-signal in increasing flow capacity of signalized intersections under certain situations have been presented in the literature. However, whether it can improve the performance of signalized intersections considering both the delay and capacity side has not been completely understood.

The lane assignment makes a great difference to the delay and capacity of signalized intersections, which have received much attention in recent five years. Unconventional lane assignment designs are believed to bring a high intersection performance which means higher capacity and lower delay. Xuan[2] first proposed the concept of TD to increase the capacity of signalized intersections when there are heavy left turns and oversaturation. The conclusion that TD can increase the capacity of signalized intersections has also been reported in the literature[3-4]. Moreover, the advantages of TD compared with other design methods have been illustrated (e. g., lower construction costs)[2, 5]. Note that TD is not considered a good option in undersaturated situations[2, 5].

In addition to the capacity, whether TD can help to reduce the delay is essential for practical implementations. Xuan[2] argued that increasing the capacity can also reduce the delay of signalized intersections under oversaturation. However, the evidence is not sufficient to support the argument. Actually, the pre-signal may cause vehicles to stop more times at an intersection, thus resulting in a greater delay. Abundant research has been conducted on the delay analysis since TD was proposed. For analytical studies, Ma et al.[3] proposed a bi-level program to maximize capacity and minimize delays simultaneously for one approach of an intersection. Nevertheless, only the delay

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at the main signal was considered for the minimization. Zhou et al.[6] used the Webster formula to obtain the delay at the pre-signal, and incorporated it into the objective function for an optimization model of lane assignment and signal timing. Additionally, the pre-main signal coordination and pre-signal itself caused extra delays. Consequently, the delay for TD might increase, which required analytical insight[6]. On one hand, the Webster formula is empirical and works for conventional isolated intersections, but no evidence supports its feasibility in the usage of TD. On the other hand, delays at the main signal and pre-signal are correlated due to abnormal characteristics of traffic operations. Therefore, it may be inappropriate to use the Webster formula to obtain delays at the pre-signal. These problems make the analytical results restrictive to some extent. For numerical studies, simulations were performed to obtain key performance indicators including the delay at 4-leg signalized intersections[7-8]. Conclusions from these numerical studies as well as the aforementioned analytical studies all indicate that TD can effectively reduce average delays. Even if conclusions from the numerical studies[7-8] are reliable, they may not hold for other types of intersections. In particular, T-intersections, which are also common in the world, should deserve much attention. Little evidence indicates that they can be simply treated as degenerate versions of 4-leg ones. If TD does not always reduce the delay for simple T-intersection scenarios, TD probably increases the delay under more complicated 4-leg settings. Therefore, research on TD at T-intersections should be fundamental and essential. Researchers have analyzed TD at intersections that are not regular 4-leg ones[9], but T-intersections are not the focus of their research. In summary, the delay issue for TD remains unclear. Moreover, there is a gap in the delay analysis for TD at T-intersections.

This study fills the gap in comparing different lane assignment design schemes, with a major focus on the delay at a simple T-intersection. A linear program is formulated for capacity maximization. Microsimulation is used for the delay analysis. As previously discussed, the pre-signal makes analytical delay formulas less tractable than ordinary ones, while simulations ensure that various assessment indicators of the intersection[7] are able to be obtained. Therefore, the numerical experiment is employed for comparing the performance of TD and conventional designs. The effects of traffic flow (volume) and the turning proportion on the delay are explored in this study. The results show that under oversaturation, TD is not always the best design. Note that the "best" means the smallest delay throughout the study. The aim of this study is to help practitioners better recognize the delay issue for TD, and select appropriate lane assignment schemes for signalized intersections.

1 Methodology

1.1 Basic assumptions

The research project is based on the following assumptions:

1) Only automobiles are considered in the composition of the traffic stream. Other modes such as buses, bicycles and pedestrians are beyond the scope of this study.

2) Traffic in the opposing direction of this specific approach does not affect traffic operations on the approach. Meanwhile, flows on the approach also make no difference to the opposing traffic, which essentially means that the effects on traffic in the opposing direction are not considered when analyzing this approach. In addition, the network effects (e.g., the spillback, Braess Paradox, etc.) of the isolated intersection are not considered either. It is the optimization of the approaching lane in isolated signalized intersections instead of the network effects, which is the research emphasis in this study.

3) Driving behaviors are assumed to be ideal in the simulation when comparing different design schemes (e.g., violations of traffic regulations are not considered).

1.2 Pre-signal timing for tandem design

Compared with capacity, delay is more directly related to travelers' feelings about the performance of intersections. Since it is difficult to directly formulate a method for delay minimization in TD, as aforementioned, the pre-signal timing is obtained by maximizing the capacity. The capacity maximizing on TD is in accordance with the previous literature[2,5], which indicates capacity maximization. The approach can be studied independently as a result of assumption[10]. The cycle length and total green time are fixed and this study mainly concerns on the approach of TD[2-3,5,8,11-12]. The optimization of cycle length and green allocation to different approaches is beyond the scope of this study. Note that right turns are not controlled by the main signal in this study.

A linear program is formulated with two decision variables g_L and g_R.

$$\text{maximize} \quad q$$

s. t.

$$q_L = qr \tag{1}$$

$$q_R = q(l - r) \tag{2}$$

$$sn_L q_L = sN_L G_L \rho \tag{3}$$

$$sn_R g_R \leqslant sN_R (c - G_L) \tag{4}$$

$$q_L \leqslant sn_L g_L \tag{5}$$

$$q_R = sn_R g_R \tag{6}$$

$$g_L + g_R \leqslant c \tag{7}$$

$$g_L \geqslant 0 \tag{8}$$

$$g_R \geqslant 0 \tag{9}$$

where g_L represents the duration of the pre-signal left-turn green time in a cycle, s; g_R represents the duration of the pre-signal right-turn green time in a cycle, s; q_L represents the maximum flow rate of left turns, pcu/h; q_R represents the maximum flow rate of right turns, pcu/h; q is the maximum flow rate of the approach, pcu/h; r is the proportion of left turns; s is the saturation flow rate per lane, pcu/h; c is the cycle length, s; G_L is the duration of the main signal left-turn green time in a cycle, s; N_L is the number of left-turn approaching lanes at the main signal; N_R is the number of right-turn approaching lanes at the main signal; n_L is the number of left-turn approaching lanes at pre-signal; n_R is the number of right-turn approaching lanes at pre-signal; ρ is the utilization coefficient.

The formulation is similar to but different from the program formulated in the first study of TD[2, 5]. Constraint (4) means that the capacity of right turns is constrained by the pre-signal, which is reasonable because right turning vehicles can move freely at the main signal. For constraint (5), inequality is used rather than equality. Owing to some traffic disturbances, the lane for left turns at the pre-signal cannot always discharge vehicles at saturation flow rate during the green phase. Left turns are much more susceptible than right turns, so equality is still used in constraint (6). Constraint (7) uses inequality, and it is found to be not binding in some scenarios. This indicates the red time setting for the pre-signal. The results of constraint (7) means that the green time at the pre-signal is sufficient to discharge vehicles. Nevertheless, setting the red time conflicts with our assumptions. The red time can be set as the green time to discharge the right-turns vehicles because right turns need not wait for the red light of the main signal. Although no vehicle is discharged within this red time at the pre-signal in theory, the treatment should provide a better timing with the stochasticity in reality. Moreover, the utilization coefficient is introduced for the purpose of robustness, which captures the fact that the green time at the main signal cannot be fully utilized. The queue in the sorting area needs to be cleared up every cycle while coordinating with the two signals. So, when the last vehicle in a queue in the area passes the stop bar at the main signal, in general, the signal should still be green and about to turn red. As a result, $\rho \in [0, 1]$ and it should be close to 1, otherwise, much green time at the junction will be wasted. The left-turn signal time is rounded. Particularly, for the scenario that the solution is $g_L = g_R = 14$, the green time duration of the left-turn phase is 15 s and the red time duration of the left-turn phase is 13 s. Right turns are not affected by the signal here.

1.3 Lane assignment schemes

There are only two approaching lanes on the approach and no through-moving vehicles. With the consideration of geometrical issues and safety concerns, the offside lane should not be used for right turns, which also matches real-world applications. In particular, full tandem cannot be achieved here. As a result, only three design schemes are practical for this approach: tandem design (TD), dedicated right-turn design (DRTD) and shared right-turn design (SRTD). The schemes are shown in Fig. 1.

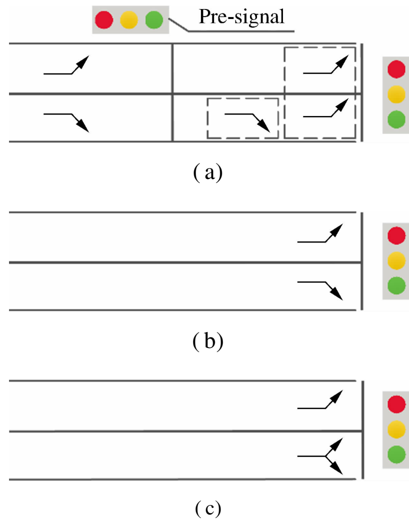

Fig. 1 Three design schemes. (a) TD; (b) DRTD; (c) SRTD

1.4 Simulation environment

For microsimulation, VISSIM is chosen for this study. Simulations are conducted at the simple T-intersection. Based on the assumption, only automobiles are considered. Time counters are set on the approach and two corresponding exits. They record the time that a vehicle passes their locations so as to obtain the delay for the approach. For the main signal timing, which is set to be fixed, 28 s is adopted for the cycle length. Since the number of lanes on this approach is small, its opposing direction is considered the main traffic direction, the green ratio of this approach is supposed to be less than 0.5. Finally, the fixed green time is set to be 8 s. Pre-signal timing is determined by the proposed linear program above. The saturation flow rate is set to be 1 800 pcu/h according to Refs. [3, 12]. Parameters regarding acceleration, deceleration, car following and lane changing are set as default. Traffic flow models are beyond the scope here. A case study in Changsha is conducted, in which the real traffic data and signal timing schemes are used.

Traffic flow is the volume in the upstream that enters the approach, and the turning proportion is the ratio of left turns. For studying the effects of traffic flow and turning proportion, the range of the two independent variables should be determined first. The range of traffic flows is determined to be [1 200, 1 900] (pcu/h). From microsimulation in VISSIM, the intersection is completely uncongested when the flow is lower than 1 200 pcu/h.

Few problems need to be addressed in extreme undersaturated traffic flow conditions. Meanwhile, when the flow is larger than 1 900 pcu/h, the intersection is totally congested in most turning proportion conditions. The delay is approximately constant under oversaturation since vehicles are bumper-to-bumper within the area for delay calculation. The area is determined by the time-recording locations. The turning proportion is set to be [25%, 90%]. Simulations show that [25%, 90%] is appropriate. When the left-turn ratio is low, the intersection is totally uncongested because right-turn vehicles need not to wait at the main signal. In addition, it is meaningless to use TD in extremely light left turns.

2 Results

2.1 Impacts of flow and turning proportion on delays

Experiments are done to overview the effects of traffic flow and turning proportion. [1 200, 1 400] (pcu/h) is set as low flow, [1 450, 1 650] (pcu/h) as medium flow, [1 700, 1 900] (pcu/h) as high flow. The medians 1 300, 1 550 and 1 800 (pcu/h) are determined to represent each flow level. Meanwhile, 25% turning proportion is considered to be light left turns, 50% to be medium, 70% to be heavy and 90% to be dominant. These are based on the observation that the proportion of left turns is no less than that of right turns for signalized intersections in general. By simulation, the delay over various traffic flows and turning proportions are obtained, as shown in Tab. 1.

Tab. 1 Effects of traffic flow and turning proportion

Flow/($pcu \cdot h^{-1}$)	Proportion/%	Delay/s		
		TD	DRTD	SRTD
1 300	25	7.95	3.84	8.73
	50	15.31	28.00	21.36
	70	25.73	91.64	23.82
	90	71.82	130.55	41.84
1 550	25	11.05	5.42	23.40
	50	24.96	53.34	41.77
	70	53.72	117.80	59.21
	90	94.49	152.58	72.25
1 800	25	25.68	9.28	39.36
	50	45.80	77.96	59.74
	70	68.44	128.11	70.83
	90	100.18	162.76	84.83

Tab. 1 shows that the delay increases with the increase of traffic flow and left-turn proportion. Right turns are not affected by the main signal, so the larger its proportion, the lower the delay will be. In addition, TD does not always have the lowest delay, which is similar to the previous studies; i. e., when the proportion of left turns is low, TD has no advantage on delay reducing. In this situation, DRTD is found to be the best lane assignment scheme. When the proportion of left turns changes from medium to high, TD starts to show its advantages. It can not only increase the capacity but also provide the lowest delay. Contradicting previous studies, TD is worse than SRTD when left turns are dominant. TD was proposed to solve signalized intersections with heavy left turns[2, 5], but this may not be true if delay rather than capacity is taken into consideration. In fact, for each design scheme, there seems to be a range of traffic flows and turning proportions that make the design outperform others. Furthermore, Tab. 1 shows that the turning proportion has more evident effects than traffic flow in design scheme selection, which solely considers the delay in this paper.

Before performing more experiments, it is necessary to conduct a sensitivity analysis of the utilization coefficient ρ. ρ is set to be 0.95 in previous sections. As discussed in Section 1, ρ should be selected close to 1, so the impacts are investigated when ρ is changed to be 0.9 and 1 in this section. The analysis is conducted over various traffic flows and turning proportions. Note that when the left-turn proportion is below 50%, the change of ρ makes no difference to the results since the linear program gives the same signal timing scheme. Therefore, the following flow and turning proportion pairs are chosen: (1 300, 90%), (1 550, 70%), (1 800, 55%). If $\rho = 0.9$ instead of 0.95, the delay will increase by 7.2%, 13.7% and 8.2%, respectively. The delay is non-negligibly larger when ρ is 0.9 rather than the case of 0.95. It is so conservative that much precious green time is underutilized. Similarly, if $\rho = 1$, a decrease of 2.2%, 2.3% and 0% for delay will be observed. The change of ρ from 0.95 to 1 seems to result in lower delays, but it only can bring a slight decrease to delay. In real applications, the green time of the main signal in TD cannot be fully utilized so as to guarantee a stable operation of TD. As a result, the choice of 0.95 for the utilization coefficient is reasonable. It continues to be used in the following sections.

2.2 Best schemes over turning proportion

According to the results above, the turning proportion seems to have a significant impact on the delay of different schemes. More experiments are conducted to investigate the effect of change in the turning proportion within the range [25%, 90%] with 5% increments. Traffic flow is controlled in [1 200, 1 900] pcu/h, and the mean of the range is 1 550 pcu/h. Results are shown in Fig. 2 (a). The delays for the turning proportions of 67.5% and 72.5% are additionally studied since the ratios are around the boundaries where the delays of TD and SRTD are comparable. Due to the variations in the delay caused by traffic conditions, the treatment below aims to represent the curves in Fig. 2(a) more precisely.

The results show that for the left-turn ratio, DRTD has the lowest delay if it is below 40%. If the left-turn ratio is above 73%, SRTD has the lowest delay. Otherwise, TD is the best. The results further prove the argument that TD is not always the best scheme even if the intersection is under over saturation. In particular, TD is worse than SRTD when left turns are dominant. The reason is probably that TD no longer has significant advantages over SRTD in terms of capacity when an extremely large number of vehicles needs to turn left. The extra delay caused by the pre-signal becomes a distinct disadvantage of TD compared with the shared-lane design. In addition, it is found that DRTD is the most sensitive scheme of response to turning proportion while SRTD is the least sensitive scheme according to Fig. 2(a). Turning proportion makes a great difference to the delay and design scheme selection.

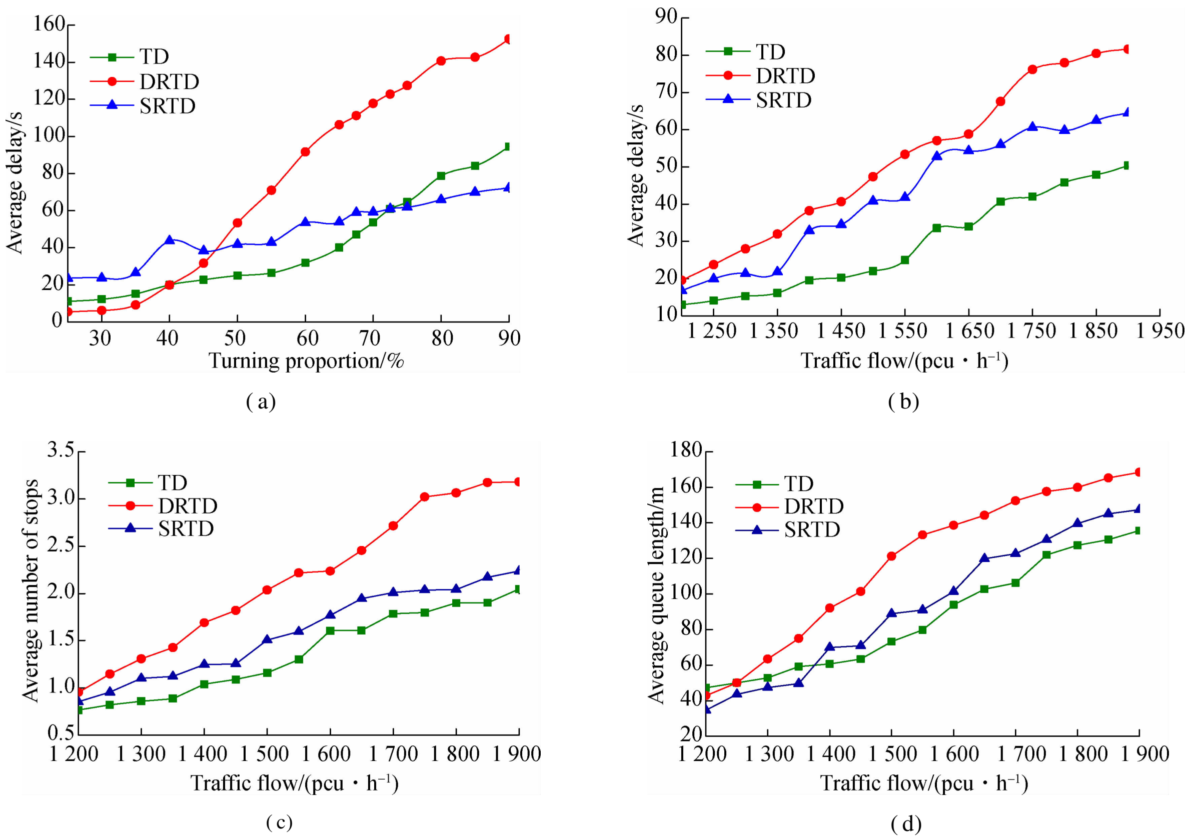

Fig. 2 Effects of traffic flow and turning proportion. (a) Turning proportion and average delay; (b) Traffic flow and average delay; (c) Traffic flow and the average number of stops; (d) Traffic flow and average queue length

2.3 Best schemes over traffic flow

The effect of changes in traffic flow on delay is determined over the range [1 200, 1 900] (pcu/h) with 50 increments while the turning proportion is maintained at 50%. Results are shown in Fig. 2(b). It reveals that TD has the lowest delay over this flow range as long as the left-turn ratio is 50%. Even when the traffic flow is 4 000 pcu/h, which approximately reaches the maximum in this scenario since the lane capacity is around 2 000 pcu/(h · lane) in road segments, it is found that TD still has the lowest delay, which is 20.3% lower than that of SRTD. TD also has an advantage in undersaturated situations. Compared with the two conventional schemes, TD obtains 43.8% and 31.3% delay reduction, respectively. Note that the reduction in delays is so considerable in this situation, it is worth investigating whether TD also has excellent performance in terms of other indicators such as the average number of stops and average queue length. In addition, although the effect of traffic flow on the delay is evident, evidence from Fig. 2 supports our argument; i. e, traffic flow makes less difference to design scheme selection than turning proportion.

2.4 Advantage of tandem design

Due to the existence of the pre-signal, the average queue length and number of stops for TD may not be the smallest. The queue length is defined to be the distance between the tail of the queue and stop bar at the main signal, which acts as an indicator of the spillback. For TD, the queue at the pre-signal is defined as the queue length. It is intuitive that the pre-signal can cause vehicles to stop more times. In addition, since the pre-signal is located in mid-block of the street, TD may not achieve the shortest average queue length. Therefore, if TD also has effect on reducing the average queue length and the number of stops with a left-turn ratio of 50%, the superiority of TD in this scenario will be self-evident. The results of effects of traffic flow and turning proportion are shown in Figs. 2 (c) and (d).

Similar to the results of delay, TD has the smallest average number of stops over the full operating range from the minimum flow to the maximum flow when the turning proportion is 50%. In terms of the average queue length, TD also has outstanding performance when the traffic flow is over 1 400 pcu/h. TD has a larger queue length according to the previous definition when the flow is very low. It is unnecessary to take into account the queue length in low traffic flow where spillback cannot occur. It is the average queue length in the situation where spillback is possibly triggered that deserves more investigation. Under this situation, TD has the shortest average queue length. Thus, TD can not only increase the capacity effectively, but also reduce the average delay, number of stops and queue length significantly. TD shows evident superiority of the three design schemes. Besides, DRTD has the worst performance in this scenario. It indicates that although the ratio of left turns to right turns is 1∶1, a dedicated right-turn lane is still not needed. Left turns and right turns are asymmetric due to the fact that a left-turn lane has much less capacity than a right-turn lane.

2.5 Design scheme selection

With traffic flow and turning proportion as the input, discriminant analysis (DA) is used to determine the best design scheme. Additional experiments are supplemented in order to make the analysis more precise. Fig. 3 shows the sample points to be used for DA. In Fig. 3(a), the circle, diamond and square means the best scheme is TD, DRTD and SRTD, respectively. Figs. 3(b) to (d) are the visualization of the relationship between the two inputs and delays, showing that the traffic flow and turning proportion are two key contribution factors to the delay. Patterns seen from Fig. 3 indicate that linear classifiers seem suitable enough for the purpose of design scheme selection. Hence, complicated methods for the classification are not needed here, which makes linear discriminant analysis (LDA) an outstanding option. R software is used for LDA.

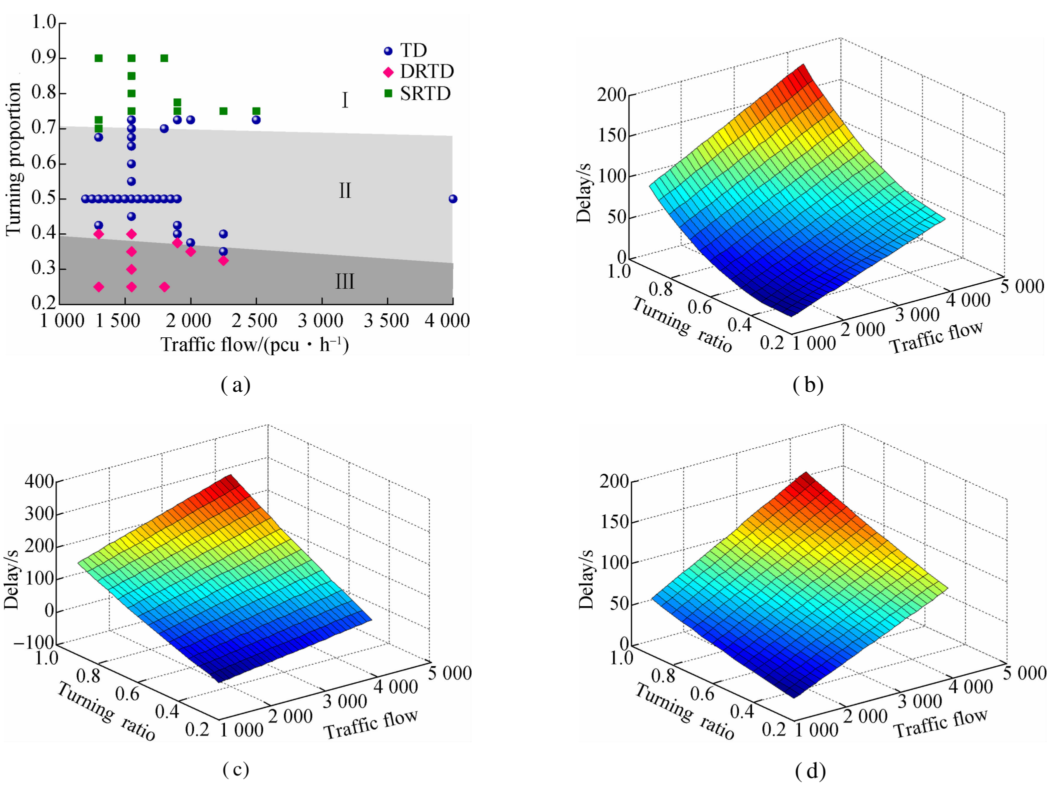

Fig. 3 Design scheme selection based on delay. (a) Design scheme selection; (b) Delays for tandem design; (c) Delays for dedicated-right design; (d) Delays for shared-right design

Results show that two linear discriminant functions (DFs) used for classifying the design schemes are obtained with an error rate of 16.1% in the training process. The plane is accordingly divided into three regions. If the data lies in Region Ⅰ, SRTD is to be selected. Regions Ⅱ and Ⅲ correspond to TD and DRTD, respectively. Slopes of the two classifiers further indicate that the turning proportion makes a greater difference to scheme selection than traffic flow, especially, between TD and SRTD. It is found that a left-turn ratio of 70% is approximately the critical point for selecting TD or SRTD over all traffic flow levels. Due to the limitation of sample size, the sample cannot be divided into two groups (one experimental group and one validation group) for testing the analysis. Alternatively, the following case study can help to validate the method.

3 Case Study

3.1 Study site

The study site is the intersection of Wuyi Road and Shuguang Road in Changsha, a capital city in southern China. Its spatial and temporal designs are shown in Fig. 4. DRTD is the current design scheme with two approaching lanes on the southern approach. This T-intersection is located in the central district of the city. In addition, there are evident queues during morning rush hours on the southern approach, though travel demand on Shuguang Road is much less than Wuyi Road. If travel demand increases in future years, the queue may start blocking the upstream intersection. Therefore, it is of significance to make a quantitative analysis of different design schemes in an attempt to reduce the delay and congestion in T-intersection. Meanwhile, the validation of LDA can be achieved here.

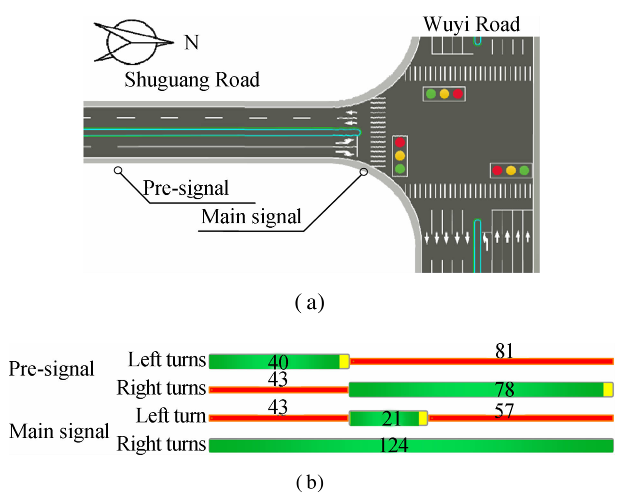

Fig. 4 The intersection of Wuyi Road and Shuguang Road (unit: s). (a) The intersection shape; (b) Signal timing for TD

3.2 Delay analysis

Since only cars are considered for our analysis, other modes have to be equivalently converted into cars. Truck passenger car equivalent (PCE) values that can accurately reflect the truck impacts on the saturation flow rate are used here to achieve the purpose[13]. Hence, the traffic flow is found to be 609 pcu/h while the turning proportion is 0.607 during morning rush hours on the southern approach. Additionally, the simulation scenario is set up. The cycle of the main signal is 124 s without all-red time. The timing at the pre-signal is as follows: 1) The green time is 40 s for left turns; 2) The green time is 78 s for right turns; 3) The yellow time is 3 s for left and right turns. Other elements of the intersection remain the same for either TD or SRTD reconstruction.

Accordingly, the simulation is conducted to compare the performance of the three schemes on the same platform. Results show that the approach is occasionally congested in current situations, which coincides with real observations. TD turns out to have the lowest average delay of 31.4 s while the original delay is 43.8 s. The decreasing rate of delays is 28.3% for TD reconstruction. With the rapid growth of motor traffic in most big cities in China, if the traffic flow increases to 800 pcu/h, this approach will become oversaturated for all the three schemes according to the simulation. Anyway, TD is still the best method with a decrease of 45.0% in the delay. In addition, it further proves that TD can also be outstanding in the undersaturated situation though it is not so effective in the case under oversaturation.

Meanwhile, according to LDA, when the traffic flow is 609 pcu/h and the turning proportion is 0.607, the probability of selecting TD is 94.2%; and for 800 pcu/h and 0.607, the probability is 94.1%. TD should be chosen under both scenarios, which agrees with the simulation result that TD is the best in both cases and the delay reduction is considerable. As a result of the consistency, the validity of our LDA is shown in this study.

4 Discussion

For the three design schemes, they have their own appropriate traffic flows and turning proportions even for the simple T-intersection. Although the basic assumptions make the specific ranges of the flows and turning proportions unable to be used in real applications directly, they provide insight that each design scheme should have its own application conditions including TD for different types of signalized intersections. TD is not always the best even if there are heavy left turns and oversaturation, at least for the partial tandem.

In any case, these basic assumptions need to be justified to further support the results in this study. According to Refs. [2, 5], the fewer the number of tandem lanes, the less counterintuitive it will be to drivers. The traffic reorganization in this study is not dramatic. With the help of traffic signs and markings, assumption 3) is far from unreasonable. Note that the validity of this assumption will be an important issue if TD is studied at more complicated intersections or in general contexts. However, it is expensive to obtain the precise saturation flow rate for different types of approach lanes due to many contributing factors.

5 Conclusion

In this paper, a fundamental study is conducted to optimize the lane assignment for signalized T-intersections. Three practical design schemes are compared. The delay minimization is the focus of analytical formulation while the capacity maximization is the objective. Some novel and important results are obtained. First, TD can not only effectively increase the capacity, but also reduce the delay, average number of stops and queue length significantly under suitable conditions of traffic flow and turning proportion. Secondly, TD can be the best choice over various traffic flow levels. Contrary to the previous research, TD also has excellent performance in undersaturated situations. The turning proportion plays a significant role in scheme selection of lane assignment. A proper proportion of left turns makes TD an outstanding option. However, the proportion should not exceed 73% or be less than 40%. When 80% of vehicles make left turns, SRTD has the best performance even under oversaturation. When 50% vehicles are left turns, even when the intersection is undersaturated, TD is the best choice in terms of not only the delay but also the average number of stops and queue lengths. When 30% of vehicles make left turns, DRTD demonstrates the best performance.

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基于 VISSIM 的信号控制 T 型交叉口车道分配方案优选

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摘要:为了改善信号控制交叉口的性能,提出了基于串联设计的非传统交叉口车道分配方法,结合仿真模拟实验对串联设计和 2 种传统设计方案进行通行能力评价和延误评价. 首先,采用 VISSIM 软件进行微观仿真,得到不同交通流量和转弯比例条件下 3 种车道分配设计方案的延误数据. 其次,以交通流量和转弯比例作为自变量,提出了基于判别分析来确定最佳车道分配设计方案的方法. 最后,采用长沙市的实测数据对研究结果进行了验证. 研究结果表明:交通流量和转弯车比例对方案选择至关重要. 与已有的文献研究结果不同,各种交通流量条件下串联设计都有着出色的表现. 此外,串联设计在左转车比例适中的情况下是最优的车道分配方案,能有效地降低延误、平均停车次数和排队长度,但其比例不宜过高或过低. 这些发现有助于科研人员和道路设计师定量地依据不同交通条件采用合适的设计方案以缓解交通拥堵.

关键词:延误; T 型交叉口; 串联设计; 交通流量; 转弯比例

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