Calculation Model of Plane Design CAD System of Highway Intersection

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Abstract. A reasonable way of organizing traffic at intersections is the key to solving problems with a mix of motorways and slow roads, as well as collisions at suburban intersections and to ensuring the safety of intersections. This article describes how the transport organization of crossings is managed from two aspects: the method of channeling crossings and the signal optimization method. The optimization of suburban highway crossings has been studied in two aspects: how to channel and control signals while concentrating on heavy goods vehicles. In the case of drainage, the main objective is to reduce collisions and to ensure operational safety with regard to the characteristics of the four modes of transport: cars, heavy lorries, non-cars and pedestrians. When designing the signal phase in the signal control, the phase is determined according to how the entry track of the heavy vehicle is drained. The calculation of the main timing parameters changes the calculation parameters in relation to the optimal cycle, depending on the characteristics of the heavy goods vehicle. The optimization scheme described in this document is used to propose an optimization scheme and to evaluate it using CAD simulation. Finally, three indicators are compared back and forth, so that it is concluded that optimized intersection points work more efficiently and safely compared to current intersections.

Keywords: CAD intelligent system; network plane design; computer aided; highway intersection
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1 INTRODUCTION

Computer-aided design (CAD) is a technology that enables the mixing of human and computer in the design profession, linking the best of human and computer performance [1]. In computer-aided design work, human ingenuity, experience and creative thinking are perfectly combined with the high speed and accuracy of the computer. The task of the computer is essentially to process, manage and exchange a large amount of information, that is, on the basis of the designer's initial ideas, judgments, decisions and the various specifications, constraints, experience, etc., the computer retrieves and extracts a large amount of design data, calculates, analyses and optimizes according to the design requirements, and displays the design results in the form of graphics or tables for the designer to make decisions by Gaikawad [2]. The results of the design are displayed in graphical or tabular form for the designer to make decisions, or are repeatedly modified by human-computer interaction to finalize the engineering design [3]. Computer-aided design allows designers to use their main energy for creative work such as program generation and modification, while the tedious, monotonous design calculations and drafting work to the computer processing, which not only shortens the design cycle, but also improves the quality of design. Highway CAD technology has been used since the 1960s, and along with the development of computer technology, highway CAD technology has gone through an integrated and systematic technology from auxiliary calculation to auxiliary calculation and drawing to data acquisition, design, analysis and optimization at the end of the last century [4].

The Finnish ROADCDA road system, which integrates data acquisition, processing and image output; the American company MROADS, which has advanced image processing and interactive design technology and embodies the perfect combination of computer hardware and road design software; and the British MXROad system (i.e., MOSS system), which is an internationally commercialized software that can be used for roads, railways, water conservancy, airports, mines, etc. by Lan and Zhao [5]. The famous software for civil engineering design, which uses a different approach to design based on cross-sections, i.e., a new "string" concept to express structures and terrain surfaces, with full flexibility in the representation of geometry, suitable for a variety of complex civil engineering design by Zanen et al. [6]. The common features of these foreign software are: built on the basis of a strong three-dimensional digital ground model or structure model, more prominent is the interactive design function of the flat and longitudinal surface, in the interface of the friendliness, data consistency, sharing, no duplication or interactive functions and other systematization have good characteristics, focusing on visualization technology, user interface technology, and seek some intelligent functions and system integration and The system is characterized by a good degree of automation [7]. Such a system has a considerable degree of automation, but also can give full play to the creative thinking of designers, has become a powerful design aid for foreign engineering designers. However, due to the design methods and habits of foreign countries, the pattern of drawings has a large gap with China, while the difficulty of making foreign software in China, so that the promotion of foreign excellent design software in China is more difficult. Road CDA system research and development began in the late seventies of the twentieth century, roughly through the exploration, improve and promote the three stages, almost covering the whole process of road design, including digital ground model, route optimization, route flat vertical and horizontal design, bridges, culverts, crossings, support structures, traffic engineering, budget estimates, three-dimensional display, etc., the application of these software in the design of highways, powerfully promote the application of these software in highway design, has strongly promoted the technical progress of the highway industry, promoting the quality and level of highway measurement and design of a substantial increase [8]. However, China's current road CDA software development is still in the scattered, independent and fragmented low-level repeated development stage, did not form the scale effect. Most of the software developed, although with a strong focus and good practicality, but generally single function, interactive design function is not strong, the lack of digital ground model and engineering database support, systematization and integration is difficult to achieve, far from being able to adapt to the rapid development of China's road infrastructure construction needs [9]. With the deepening of urbanization and the continuous expansion of urban area, the area of urban-rural combination is also gradually expanding by Mandal et al. [10]. As a form of road between urban roads and rural roads, the road function and the role played by suburban roads are becoming more and more important. The traffic composition of a suburban road is different from that of an urban road, and different from that of a rural road, which is dominated by non-motorized vehicles and pedestrians, but is a mixture of various types of traffic. As a node that brings together urban traffic and rural traffic, mixed traffic problems and conflicts are more prominent at suburban road junctions [11].

Therefore, it is necessary to study the traffic organization of suburban highway intersections. In this paper, three typical suburban highway intersections in Changsha are selected for traffic survey. By collating the survey data, the size and composition of the traffic volume and the characteristics of the driving speed of large trucks at suburban highway intersections are analyzed, and the traffic problems existing at the intersections are summarized. Then, taking the separation of traffic and reduction of traffic conflicts as the starting point, at the same time, according to the characteristics of large trucks themselves, combined with some safety problems of large trucks at intersections, some optimization measures are proposed from two aspects, namely traffic canalization and signal control. As the large proportion of large trucks is a unique traffic characteristic of suburban roads, large trucks are separated from motor vehicles and taken as a separate object of study, and some suggestions are made for traffic circulation, while some measures for non-motor vehicles and pedestrians are also proposed. In addition to the determination, it can also be combined with the determination of large according to how to drain the large vehicle entrance lane, and at the same time, the relevant calculation parameters of the optimal cycle in the Webster method are modified according to the starting characteristics of large trucks; finally, through the analysis of the traffic problems existing at the case intersection, a reasonable drainage scheme and a scientific timing scheme are proposed, and a simulation evaluation is carried out using the CAD system.

2 TRAFFIC ORGANIZATION AND CHANNELIZATION METHODS FOR SUBURBAN ROAD INTERSECTIONS

2.1 Traffic Organization Optimization

Traffic organization optimization design refers to the use of scientific traffic management methods and measures, in the limited road space to reasonably divide the time, road, vehicle type and flow direction to use the road, improve the road capacity as well as the safety of traffic participants, so that the road traffic is always in an efficient and orderly operation between the state, as shown in Figure 1. For the intersection of the traffic group optimization, there are three requirements as follows. (1) To widen intersections to the maximum extent possible using available land resources, to drain the inlet lanes, and to increase the number of guide lanes and exit lanes where possible so that the capacity of intersections and road sections is as consistent as possible. (2) Signal timing should be rationalized so that there are no free periods at junctions as far as possible. (3) The corresponding traffic signs and markings should be improved as far as possible so that the spatial and temporal rights of way can be better highlighted.

Based on the traffic characteristics of suburban roads, the following principles should be considered when optimizing suburban road junctions.

(1) Principle of traffic separation. At intersections, vehicles travelling in different directions, vehicle types and speeds, as well as pedestrians, should be separated in time or space so that they travel in their respective lanes during their respective phase times. Temporal rights of way are clarified by setting up signal phases, while spatial rights of way can be clarified by channelization of traffic markings. (2) Principles of traffic volume control and regulation. Guidance at intersections for different types of vehicles with different turns, e.g., setting up left turn lanes, etc.; or restrictions on vehicles, e.g., speed limits at intersections, no U-turns, etc.

The following seven principles exist for the drainage of suburban road junctions.

(1) Ensure safety. The complex composition of traffic at suburban road junctions and the higher speeds at which vehicles travel make them more of a safety issue and should therefore be the primary principle when it comes to drainage. (2) Maintain some flexibility. Suburban roads are a

dynamic development process, as the economy grows and construction continues, the volume of traffic on suburban roads grows and the composition of traffic changes from time to time. It is therefore important to consider the possibility of future development when draining the roads and to maintain a certain degree of resilience in the suburban roads. (3) Control of land use. The suburban roads are already in a land-stressed area and should be drained as economically as possible. (4) Compliance with specifications. The relevant facilities in the drainage, such as safety islands and various traffic signs and markings, should be set up in accordance with the relevant specifications and standards and should not be changed at will. (5) Convenient and straightforward. In the course of the drainage process, the routes for vehicles and pedestrians should be as clear, natural and smooth as possible, avoiding sharp turns, detours or reversals as far as possible, to ensure that all types of traffic flows can drive safely and quickly through the intersection, as far as the site conditions allow. At the same time the traffic flows of different vehicle types should be separated so that the various traffic flows can travel in their own lanes.

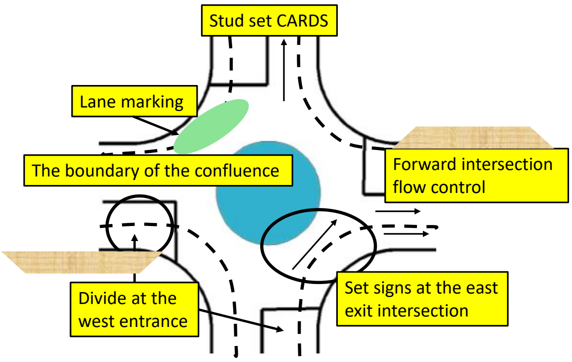

Figure 1: Optimized traffic organization design.

2.2 Motorway Drainage Design

From the traffic composition survey in the previous section, it can be concluded that the number of motor vehicles accounts for the largest proportion of traffic on suburban roads, and therefore the focus should be on motor vehicle ducting. The analysis of traffic characteristics at intersections in the previous section shows that motor vehicle-non-motor vehicle conflicts are a serious problem. Therefore, the main objective of the motor vehicle canalization should be to reduce the number of conflicts and increase the capacity. The following principles apply to motor vehicle lane drainage. (1) The area of the intersection should not be too large. Intersection area is too large will have the following disadvantages: First, it will make the vehicle in the intersection of driving more scattered; Second, it will increase the vehicle through the time, which is equivalent to indirectly increase the delay of the vehicle; Third, it will reduce the safety of vehicles through the intersection. (2) intersection set safety island, all kinds of traffic marking signs and other channelization measures set methods and requirements should be in accordance with the relevant norms and standards, and cannot be changed at will. (3) Separate different types of vehicles from each other spatially by setting up traffic islands and delineating lines in a reasonable manner. At the same time, the setting should ensure that the routes for all types of traffic flow are as smooth and simple as possible, avoiding dangerous routes such as sharp turns and ensuring that they are easy for drivers to understand and safe to drive. When traffic flows intersect, it should be ensured as far as possible that they do so at close to right angles. The various points of conflict at intersections should also avoid overlapping and must be spatially separated. With the main aim of reducing traffic conflicts, motor vehicle canalization can be studied in terms of widening of the import lane, rationalization of left-turn lanes and traffic islands and guide lines. The widening of the inlet lane is intended to increase the number of inlet lanes, subject to site conditions, in order to increase the capacity of the intersection of a high traffic volume suburban road. The widening of the inlet lanes is intended to increase the number of inlet lanes. After widening, the inlet lanes need to be reclassified to clarify the function of each inlet lane, which will reduce the number of traffic conflict points. Depending on the proportion of vehicles turning at the intersection, the function of the inlet lane can be rationalised so that vehicles of different types and turns can move in the defined lane. Depending on the volume of traffic, the following will briefly describe several scenarios of inlet lane classification. Depending on the number of inlet lanes, there are several combinations of inlet lanes (divided into the three cases of four inlet lanes, three inlet lanes and two inlet lanes), as shown in Figure 2.

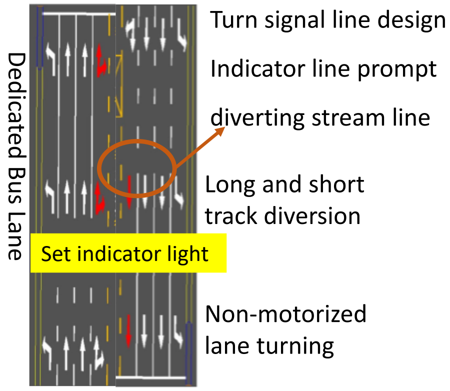

Figure 2: Schematic diagram of the functional division when the inlet lane is a four-lane road.

When widening an intersection, the two main factors to be considered are the length of the inlet lane y and the length of the exit section z. When setting the length of the inlet lane y should mainly consider the need to turn the vehicle can be smoothly and safely from the straight lane queue of the last car side into the turn lane, so y is generally by the red light during the number of vehicles waiting to go straight to decide, but y set length should not be too long, generally 50-70m; set the length of the exit section z is mainly considered just from the intersection to complete the turn of the vehicle, such The length of the exit section z is set to take into account the vehicles that have just completed their turn from the intersection, as the speed of these vehicles is low and cannot affect the normal driving of the vehicles going straight through the intersection, so z is generally set at 20-40 m. The widening is shown in Figure 3 below.

Due to the traffic characteristics of non-motorized vehicles, they should be separated from motorized vehicles at intersections as far as possible, or a special traffic area should be designated for them, thus reducing the impact on other vehicles. Some sections of suburban roads are mixed for motorized and non-motorized traffic and do not have special non-motorized lanes, or are simply delineated and segregated, but some motorists do not follow the traffic rules and tend to occupy the motorized lanes, which adds to the confusion at the intersection.

If the non-motorized traffic flow at the intersection is large and land conditions permit, it can be channelized separately to separate the various types of conflict points from each other, so that all types of traffic participants have a clear view during their journey and can clearly grasp the direction and route of other traffic flows. In view of the characteristics of non-motorized traffic mentioned in the previous section, the intersections should be canalized in several ways, such as separating the machine from the non-motorized traffic and turning left for non-motorized traffic, in the following ways.

(1) Set up lanes or dividers ① Where land is available, set up non-motorized lanes to separate them from motor vehicles, to improve the mixed traffic situation between motor vehicles and non-motor vehicles to a certain extent. ②Where a non-motorized lane has been provided but the traffic volume is high, a machine-non-motorized segregation belt can be provided on the original non-

motorized divider at ground level to mandatorily separate the two, so as to prevent motor vehicles from occupying the non-motorized lane when entering the intersection.

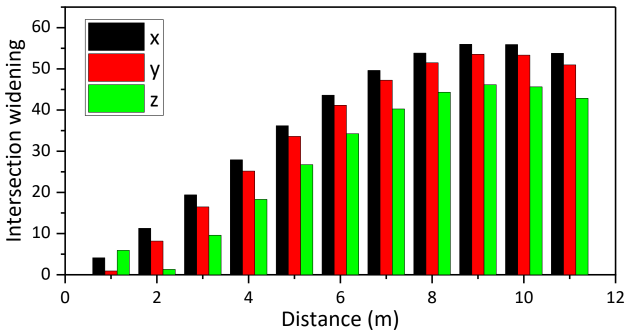

Figure 3: Standard intersection widening.

(2) Set up special right-turn lanes for non-motorized vehicles. In cases where there is a large volume of right-turning non-motorized traffic and where land is available, consider setting up special right-turn lanes or special driving areas for non-motorized vehicles, and then separate the special lanes or special areas from the motor vehicle lanes by setting up traffic islands, traffic markings and green belts. This can effectively reduce the conflict between motorists and non-motorists at the intersection, thus improving the safety of drivers.

(3) Move the parking line of non-motorized vehicles forward Generally speaking, non-motorized vehicles start faster and their drivers are used to passing through the intersection quickly. If the parking line is appropriately moved towards the intersection compared to the parking line of motorized vehicles, then it can effectively improve the situation where a large number of non-motorized vehicles stay at the intersection and affect other vehicles. It also helps to reduce conflicts with motor vehicles when they cross the stop line together and improves the traffic order at the intersection. This method eliminates conflict points 2 and 3 of the straight ahead non-motorized conflict points in the diagram.

3 COMPUTATIONAL MODEL ANALYSIS

3.1 Example of a Three-way Intersection Application

The intersection of Avenue A and County Road X is a typical suburban road in Changsha, which runs east-west and is located between the South High Speed Rail Station and the airport. It plays an important role in the dispersal of both passenger and freight traffic.

The design speed of Avenue A is 60km/h. Previously, the main road was 6 lanes in both directions and 1 lane of mixed traffic on each side, making a total of 8 lanes. The market (Agricultural Products Logistics Centre) was relocated to this area and there is a large logistics park nearby, resulting in an increasing amount of traffic. As a result, the secondary road was widened, with the main road remaining at 6 lanes in both directions and the secondary road being widened by one lane to 2 lanes on each side, in order to meet the traffic demand for road capacity. (The survey was conducted on a one-hour traffic volume at the Avenue A-X intersection, and the software was only able to simulate the intersection for one hour), where there were no turnarounds in the east-west direction, and the results of the survey are shown in Figure 4.

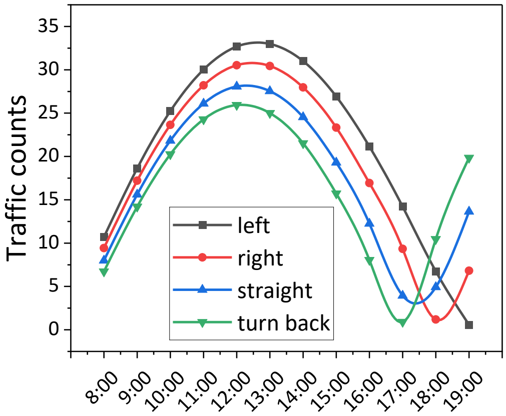

Figure 4: One-hour traffic volumes at Avenue A - Intersection X.

The site investigation and subsequent analysis of the A Avenue-X intersection in Changsha concluded that the following traffic problems exist at the intersection.

(1) Conflict issues

As County Road X035 in the north-south direction is a two-lane road in both directions, the inlet road has not been channelized and lane demarcation lines, road center lines, guide arrows and other corresponding traffic markings are missing. When vehicles drive to the intersection, there will be confusion in the driving trajectory, leading to more conflict points and prone to traffic accidents. ② As left-turning vehicles in the north-south direction are using the same phase as the direct traffic, it will lead to an increase in the conflict problem at the intersection, thus affecting the capacity of the intersection. The right turn on the main east-west road is always released, which is prone to conflict with left-turning, direct traffic on the side roads.

(2) Safety of large trucks

Due to the presence of a logistics park around the intersection, there are more safety problems with large trucks travelling straight east-west.

The longer time required for large trucks to start will increase delays for ordinary small vehicles and affect their normal passage. When large lorries are lined up with ordinary small vehicles waiting for the green light, they will block the view of the drivers of ordinary small vehicles behind them, resulting in their not being able to obtain the information of the signal in time. The deceleration time required for large trucks to enter the intersection is longer than that for ordinary small vehicles, but there are no relevant deceleration signs at the intersection to remind vehicles to slow down in advance when entering the intersection, which may lead to collision between large trucks and other vehicles due to untimely deceleration.

3.2 Model Analysis

By analyzing the two existing problems at the Avenue A-X intersection, it is clear that the main causes of these problems are unreasonable intersection drainage and unreasonable signal control schemes. Therefore, the following are two aspects of the intersection's traffic problems that can be solved through the optimization of signalization and signalization.

(1) The north-south direction is a county road and there is unused land between the driveway and the surrounding businesses, which could be considered for paving as a concrete surface and adding a non-motorized lane. (2) The north and south inlet lanes will be channelized to provide left-turn, direct and right-turn lanes, and traffic markings such as road center lines, lane dividers and

guide arrows will be improved. (3) As there are more large lorries and some buses in the east-west direction, in order to separate the large vehicles from the small ones, consider making the main road for small vehicles only and the secondary road for large vehicles only. By removing one straight lane from the five lanes at the east-west main road inlet lane, the barrier is shifted by one lane width in the direction of the main road, making the secondary road a three-lane road, thus draining the secondary road into four lanes at the inlet lane, one left-turn lane, two straight lanes and one right-turn lane. As the buses entering the east-west direction are only going straight east-west, one of the straight lanes in the auxiliary road inlet lane can be set to allow buses only, with the other three lanes being for large trucks only. (4) As the east-west auxiliary lane is set to allow only large trucks to pass, it is easy for large trucks to clash with small vehicles turning left on the main road when making U-turns. Considering that there is a T-junction before and after this intersection, large trucks can make U-turns at these two T-junctions, so the left-turn lane on the auxiliary lane is prohibited from making U-turns. (5) As there is no segregation between the east-west direction on the side road and the non-motorized road, only road markings, considering the safety of large trucks and non-motorized vehicles, it is suggested that the two be separated by railings or segregation belt, which can also improve the phenomenon of motor vehicles occupying the non-motorized road for parking. (6) Two signals are provided in the east-west direction, one for the main road and one for the secondary road, with the same signal timing. (7) At the side of the roadway entering the intersection, set up corresponding deceleration signs to remind vehicles, especially large trucks, to slow down in advance.

The modified phase matching method is used for the timing calculation of the signal phase. The data from the survey are all converted to standard trolleys by the conversion factor and then summed to the traffic equivalent for the calculation of the saturation flow and then the timing calculation, the conversion factor is shown in Figure 5 below, so this intersection is flatter, so the slope G is taken as 0 and fg is the correction factor for the slope and large vehicles.

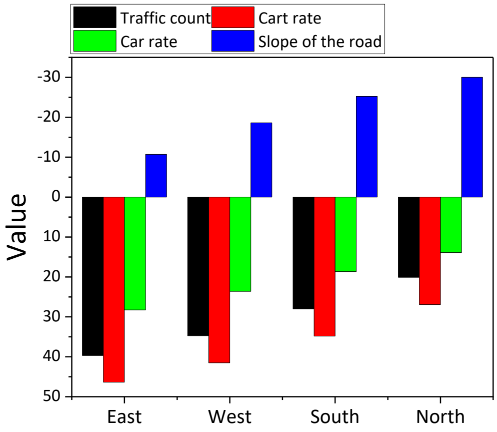

Figure 5: Timing parameters table.

Further, we analyze these parameters for maximum flow ratios:

$$Q_1 = \max(q_1, q_2, .., q_n) = 0.12 \quad (1)$$

$$Q_2 = \max(a_1, a_2, .., a_n) = 0.45 \quad (2)$$

$$Q_3 = \max(b_1, b_2, .., b_n) = 0.75 \quad (3)$$

$$Q_4 = \max(c_1, c_2, .., c_n) = 0.57 \quad (4)$$

Sum of maximum flow ratios for each phase.

$$Q = Q_1 + Q_2 + Q_3 + Q_4 = 1.89 > 0.98 \quad (5)$$

This means that the phase design is reasonable and that the timing calculation can be continued.

The share of large trucks in the traffic composition is 5.27%, so l according to the modified formula:

$$l = 10 * 5.27\% = 0.527 \quad (6)$$

The yellow time is taken as 4s and no all-red time is set, so the loss time for each phase is:

$$lq = l * Q = 10 * 5.27\% * Q = 0.527 * 1.89 = 0.99 \quad (7)$$

Signal optimum period:

$$lq = 0.99 \rightarrow 0.89 \quad (8)$$

The following timing scheme is obtained: the signal period is 90s.

Phase I: 27s for green light and 4s for yellow light.

Phase II: 17s for the green light and 4s for the yellow light.

Phase 3: 15s for the green light and 4s for the yellow light.

Phase 4: 18s for the green light and 4s for the yellow light, as shown in Figure 6 below.

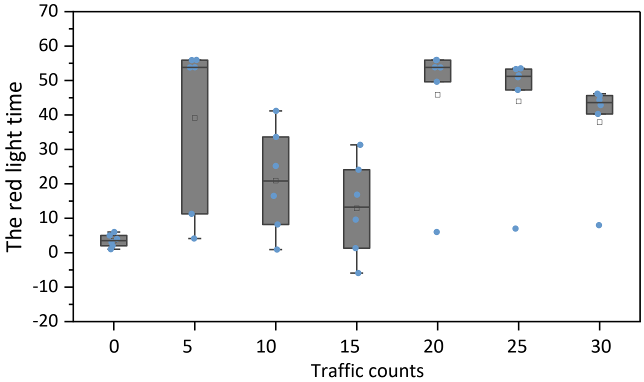

Figure 6: Optimized solution signal timing.

This paper presents two simulations of the current situation of the Avenue A-X intersection and the optimized intersection based on the actual investigation by means of CAD microsimulation software. The modelling simulation process of CAD is presented in the following steps, taking the intersection status quo simulation as an example.

(1) Establishing a simulated road network

Import the base map. Import the schematic diagram of the location of the intersection as a road network map into CAD. Create a road network. Once the base map of the road network has been imported, CAD can create a road network by adjusting the scale to the background of the road network map. First, draw the road section (Link) in CAD, according to the number of lanes at the intersection in each direction of the import and exit lanes to depict the road section, a lane that is a road section. The direction of travel of the vehicles is the direction of the road section. Once the road sections have been drawn, the next step is to connect the different sections with connectors, which is the second step in creating the road network. In addition to this, the connectors can also simulate left or right turning traffic at intersections.

(2) Setting of basic data

The main parameters are set and calibrated according to the specific conditions of the intersection, and the following parameters are set for the average headway time distance, desired speed, etc. The average headway is taken as 2.3 s. Queue length: F less than 5km/h at the beginning and F greater than 10 km/h at the end. Desired speed: 50 km/h for small cars and 30 km/h for large trucks. Distribution of vehicle models: 90 per cent small cars and 10 per cent large trucks. The acceptable deceleration value for forced channel changes is -1 m/s^2.

Enter different types of traffic volumes depending on the vehicles travelling in each lane. According to the previous traffic volume table for the Avenue A - X intersection, traffic volumes are entered on each lane by vehicle type. For example, all types of motor vehicles can be entered on the existing auxiliary lane, but after optimization the auxiliary lane is dedicated to large vehicles, so only traffic volumes for large vehicles can be entered. As can be seen from Figure 7, the optimization has resulted in a considerable improvement in overall intersection delays, with a 40% reduction in vehicle delays at the Avenue A - X intersection after the optimization compared to the existing scheme.

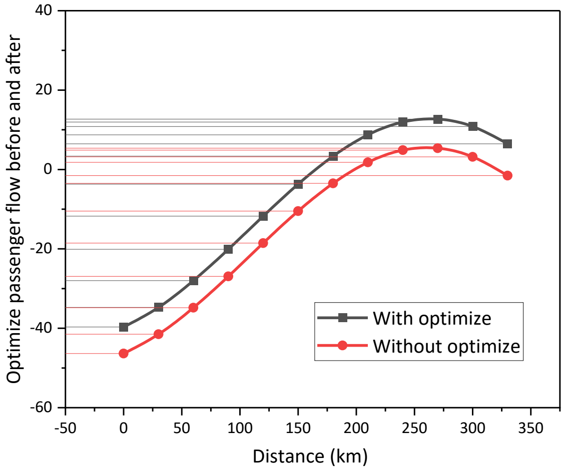

Figure 7: Line graph comparing delays before and after optimization.

After the optimization, the average queue lengths at each inlet lane of the intersection have been reduced in general. After optimization the average queue length for vehicles at the A-Avenue-X intersection has improved by around 30% compared to the pre-optimization period. By comparing the above indicators, it can be concluded that the optimized intersection has improved significantly in terms of both operational efficiency and safety. As a result of the separation of the north-south and left-turn directions, delays on the north-south inlet lane have been significantly improved and queue lengths on the south inlet lane have been significantly reduced. The east-west auxiliary lane is set up as a lane for large vehicles, and the signal control of small vehicles turning right on the main road reduces conflicts and also reduces the danger of large vehicles to other vehicles to a certain extent.

4 CONCLUSION

The fact that suburban roads are in the transition zone between urban and rural areas makes them have the dual characteristics of urban roads and rural roads. The lack of adequate traffic control measures at suburban highway intersections, the large proportion of large trucks, the serious phenomenon of mixed traffic, the weak safety awareness of traffic participants and the prominent violation of regulations have led to concerns about the safety of suburban highway intersections. How to reasonably organize traffic at intersections is the key to solving the problem of mixed fast and slow traffic and conflicts at suburban highway intersections and ensuring the safety of intersections. This paper discusses how to manage the traffic organization of intersections from two aspects: the intersection canalization method and the signal optimization method. The intersection optimization of suburban highways is studied from two aspects, namely the method of channelization and the method of signal control, while focusing on large trucks. Drainage is discussed in relation to the characteristics of four types of traffic flows: motor vehicles, large trucks, non-motor vehicles and pedestrians, with the main objective of reducing conflicts and ensuring operational safety. The design of the signal phase in the signal control considers the determination of the phase according to how to drain the large vehicle inlet lane. In the calculation of the main timing parameters, the calculation parameters related to the optimum cycle are modified according to the characteristics of large trucks. An optimization scheme is proposed using the optimization methods mentioned in this paper, and then evaluated by CAD simulation. Finally, the three indicators are compared before and after, and it is concluded that the optimized intersection operates more efficiently and safely compared to the current intersection.

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