Study on Quantitative Analysis of Traffic Conflicts in Traffic Impact

by
Lei Du
Graduate Student
Transportation Research Center, Beijing University of Technology
Tel: 86-010-67393052
Fax: 86-010-67392991
Email:duduleilei121@163.com

Xiaokuan Yang
Professor
Transportation Research Center, Beijing University of Technology
Tel: 86-010-67391678
Fax: 86-010-67392991
Email:xiaokuan@hotmail.com

Lei Lei
Graduate Student
Transportation Research Center, Beijing University of Technology
Tel: 86-010-67391678
Fax: 86-010-67392991
Email:yuwenleilei@126.com

ABSTRACT:
Traffic impact studies (TIS) have been required by transportation agencies to evaluate the potential transportation impacts of the proposed development on the surrounding neighborhood since 2001 in Beijing. The analysis on the negative aspect brought by proposed projects in terms of improper location and excessive number of driveways or inappropriate opening of median becomes the focus of TIS. Traffic conflict is one of the main traffic safety problems that researchers are trying to understand. However, the analysis of the traffic conflicts generated by proposed development has been so far limited to qualitative interpretation and conflict diagrams in traffic impact reports, which makes it difficult for traffic professionals to evaluate traffic organization/circulation plans. The objective of this paper attempts to explore to quantify traffic conflicts analysis. Concept of conflict complexity is，for the first time, introduced in this study as a new evaluation indicator. The model to estimate conflict complexity is then built up by putting vehicle-bicycle conflict, vehicle-pedestrian conflict and vehicle-vehicle conflict into consideration. This indicator can be used to quantitatively determine if traffic organization and circulation proposed in TIS report is justified. Finally, based on the data from 65 TIS reports from Beijing city the threshold values for criterion are worked out in the study. The result from this study will help transportation agencies make decision for the proposed projects in quantitative manner.

INTRODUCTION
A lot of traffic impact studies (TIS) of development projects have been carried out since 2001 in Beijing based on the requirement of planning regulations issued by Beijing Urban Planning Committee in 2000. TIS has played positive role in coordinating the relationship between city development and transportation infrastructure construction as well as in relieving severe unbalance between traffic supply and demand. In general, there are three elements involved in TIS in Beijing. They include change of v/c ratio at intersections, quality of public transit service, and traffic organization/circulation. The first two elements have been studied for many years in Beijing and the corresponding evaluation indicators are given in quantitative format as indicated in the study [1,2,3]. However, the analysis of traffic organization has always been discussed in qualitative way in TIS, resulting in no-conclusion state. The very reason for this is that there is a lack of criterion to dictate analytical process of traffic organization. Therefore, this paper attempts to develop a new evaluation indicator named "conflict complexity" as a criterion to determine if the traffic organization at proposed development area meets the requirement of traffic conflict perspective.

The traffic organization is defined in this paper as ways of controlling and managing on accesses of proposed development and connections to the adjacent roadways. Three types of traffic conflicts at proposed development area can be categorized based on the interactions between traffic flows. The first type of conflict in this study refers to the conflict between motor vehicle and non motorized vehicles (such as bicycle). This type of conflict is vital in the evaluation of TIS because the conflict will result in serious injury or casualty. The second type of conflict denotes the conflict between motor vehicle and pedestrians in light of the fact that high percentage of people make their trips by walk. Like the first type of conflict this conflict is also considered an important factor in projects of the evaluation of traffic impacts (TIS). The third type of conflict deals with conflicts among motor vehicles. This kind of conflict is often talked about in safety studies. As is known this kind of conflict diminishes at signalized intersections because signal indications assign right-of-way for traffic movements from different directions, resulting in the decrease of possible conflicts between vehicular traffic.

In the process of evaluating a project these three conflicts are often discussed in qualitative way

without giving specific answer to the question as if the traffic organization or circulation plan is acceptable. To overcome this deficiency a mathematical function reflecting the degree of conflicts from three aspects: vehicle versus bicycle; vehicle versus pedestrian, and vehicle versus vehicle is built up to quantitatively evaluate a traffic organization plan. The given model is the product of these three conflicts with consideration of other constrains. The higher the value of the conflict complexity, the severer the conflicts are.

For any TIS there are three classes for evaluation conclusion. They are: acceptable; rejected and needing modification. The class of needing modification means the project itself to be modified but not to be reconstructed. Each class falls in corresponding values. The corresponding values are determined based on the results from the studies of 65 TIS reports in Beijing.

It should be mentioned that there are very few studies related to modeling of traffic conflicts in TIS from literature review. This is the first exploration in this area.

LITERATURE REVIEW

With the rapid development of urban areas, more and more complex conflicts in air traffic and roads are affecting people's lives. There are many studies of traffic impact at home and abroad. Traffic conflict is one of the main traffic safety problems that researchers are trying to understand. The traffic conflicts which have been studied most are those air traffic's. The studies about surface transportation include traffic conflicts at highway intersection and traffic conflicts on urban roads.

There are many aspects of studies of traffic conflicts on urban roads. For example, the influence of driving behavior to traffic conflicts, the relationship of traffic flow complexity and traffic conflict, vehicle-bicycle conflicts, etc. Several papers that used traffic conflicts at signalized and unsignalized intersections as a tool for evaluating the relationship between the accidents and conflicts are also described.

A study by Parker and Zeeger in 1989 was performed to produce guidelines for collecting conflict data in the United States. This report produced a guide for engineers, which addresses issues such as sample size, conflict types, conflict definitions, and conflict analysis. [4] The paper written by Xing Ge, Jian Lu presents a relation model between driving behavior and conflict at unsignalized intersection based on the impact on traffic operating and safety. [5] The paper written by studies the driving and riding behaviors during intrusion conflicts in vehicles-bicycles laminar flow, which means that some bicyclists will intrude the lanes reserved for vehicles from time to time. A cellular automata model is proposed to model such conflicts and examine the variation process of traffic flow rate according to the density of vehicles and bicycles. [6]

OBJECTIVE OF THE STUDY

The objective of this study is to propose a comprehensive indicator to evaluate traffic organization and circulation at proposed development site to determine if the project is accepted, or needed to modify, or rejected from perspective of traffic conflict intensity. To this end conflict complexity has been introduced in this study and its mathematical equation is built in order to quantify the conflicts brought about by the proposed development. The utmost motivation behind conducting this kind of research is to simplify the process of TIS evaluation in traffic conflicts and avoid uncertainty in discussing traffic organization and circulation.

METHODOLOGY

It's critical for transportation agencies reviewers in TIS to evaluate the interference of the traffic

generation of proposed development to the traffic of other roadways or arterials at site access intersection within the study area. This interference is one of critical elements in TIS. Proper location of access site of proposed development can make existing road network work well, eliminate the traffic congestion and potential dangerous on safety, and keep the trips safe and convenient. A parameter called "conflict complexity" is proposed in this study as a quantitative indicator of the evaluation of traffic organization in the paper. Conflict complexity represents intensity and the levels of conflicts among any traffic movements within the nearest intersection caused by the proposed projects. This indicator is used to evaluate levels of traffic organization on the basis on type of conflicts within affected area. Its mathematical equation can be expressed as follows:

$$C = \sum_{1}^{m}\left[K(1+\lambda_B\delta_B)(1+\lambda_P\delta_P)\sum_{1}^{n}\sqrt{\frac{N_i+N_j}{2}}C_n \right] \quad (1)$$

Where: C—conflict complexity;

m—the number of accesses connected to the roadways

K—distance punishment factor, and its values are shown in Table 1;

C_n—conflict intensity corresponding to nth conflict (n=1,2,…9), the value is shown in Figure 2;

λ_B—vehicle-bicycle conflict factor;

$$\lambda_B = \begin{cases} 0.5 \text{ residential area, commercial area, office building} \\ 0.2 \text{ otherwise} \end{cases}$$

δ_B—conditional variables;

$$\delta_B = \begin{cases} 0 \text{ there is no vehicle - bicycle conflict} \\ 1 \text{ otherwise} \end{cases}$$

λ_P—vehicle-pedestrian conflict factor;

$$\lambda_P = \begin{cases} 0.5 \text{ residential area, commercial area} \\ 0.2 \text{ otherwise} \end{cases}$$

δ_P—conditional variables;

$$\delta_P = \begin{cases} 0 \text{ there is no vehicle - pedestrian conflict} \\ 1 \text{ otherwise} \end{cases}$$

N_i—the number of lane of conflicting flow i;

N_j—the number of lane of conflicting flow j.

DISCUSSION OF PARAMETERS

Distance Punishment Factor K

The value of K, defined as punishment factor, reflects how distance from access (driveway) connected to the proposed development to an intersection, representing the impact of access on the performance of intersection. The longer the distance is, the less the impact is, and vice versa. The values of Table 1 reflect some findings from Beijing. There have been some studies in Beijing on the design and layout of driveways close to a nearest intersection. The studies show that when distance K is 50m or shorter there is a great impact on the traffic. Besides, crashes at access point are often seen due to the visibility problem and unexpected maneuver of drivers from driveways. Likewise, when this distance is

150m or longer this impact diminishes and can be neglected as indicated in the study [7]. It should be noted that functional area and corner clearance defined in Access Management Manual have not been so far addressed in the design criterion of intersection in China. Therefore, there is no standard to follow in identifying where access can best be located. The values in Table 1 can be used only for Beijing.

Table 1 Punishment Factor

Distance from Access D (m)	≥150	50-150	≤50
K	1	1.25	1.5

The distance from access D is measured from the central line of the driveway (access) to the curb of near sidewalk as shown in Figure 1.

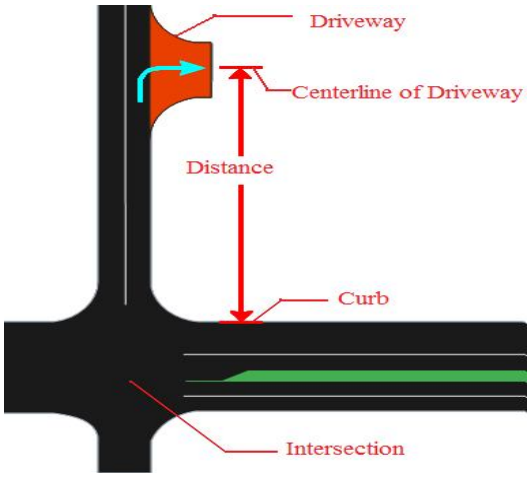

Figure 1. Definition of Distance from Driveway to Intersection

Vehicle-bicycle Conflict Factor

As is known bicycle travel possesses high percentage of the total trips in urban area. This is particularly true in small and middle sized cities in China, where car ownership is relatively low. Even in major cities like Beijing there are a lot of bicycle riders. The latest (2006) OD survey for commuter travel conducted by Beijing Municipal Commission of Transportation showed that there were 30.3% of commuters in Beijing who travel by bicycle indicating that bicycle is still an important transportation means in intra-city travel in Beijing. It is important to put vehicle bicycle conflict into consideration when conducting traffic organization work.

If traffic organization is design such that bicycle and vehicular traffic are running in separated way, it is considered that there is no conflict between bicycle and motor vehicle. At this time the conditional factor δ_B is zero. However, in most cases bicycle and automobile can't be operated into segregated way due to the constraints of land use and right-of-way issues. It is very difficult to estimate exact impact of bicycle-vehicle conflict on traffic organization with regard to different location or land use feature. Surveys have been conducted to investigate such impact. The results from survey show that majority of people think that conflicts between bicycle and vehicle at residential, whereas commercial and office areas are crucial. Statistically, this group of people possesses 71% of all surveyed. Therefore, the vehicle-bicycle conflict factor λ_B is 0.5 for residential, commercial and office building area; whereas 0.2 for other area.

Vehicle-pedestrian Conflict Factor

This factor is also important in the traffic organization plan because vehicle pedestrian conflict often results in the serious injury or casualty, which will greatly degrade the image of local government. Facing pressures from the public to protect peace and calm of the community all levels of government in China have to make efforts to exercise traffic calming in both existing community and new development. To this end human-centered development and land use strategies have been initiated in urban planning. From transportation perspective it is required that the community should be planned and constructed to be pedestrian oriented.

In this model vehicle-pedestrian conflict factor λ_P has been introduced in order to reflect the levels of traffic organization. In general if facilities for pedestrians have been adequately provided in the development such as provision of overpass or underpass for pedestrians to cross street, installation of signal for pedestrians to cross, it is considered to separate pedestrian flow from vehicular traffic thoroughly. Under this circumstance the conditional variable for vehicle-pedestrian conflict δ_P is zero. Based on the study [8] conflicts between pedestrians and motor vehicles are more vital in residential and commercial areas than in other areas. Results from this study show that residents and shoppers are more sensitive to the provision of pedestrian's facilities and prone to live in the community and do shopping if their activities are free from vehicular traffic. Therefore, the value of vehicle-pedestrian conflict factor λ_P is 0.5 for residential and commercial area, whereas 0.2 for other area.

Conflicts Intensity

From the Equation 1, it can be found that the most critical thing is to identify the conflict intensity of various traffic conflicts that drivers have to experience caused by the traffic organization plans at site.

(1) Classification of traffic conflicts

At present, there are various methods to classify the traffic conflicts [9]. Based on the possible collision of any two traffic flows from different directions conflicts can be classified into 9 classes as shown in Figure 2.

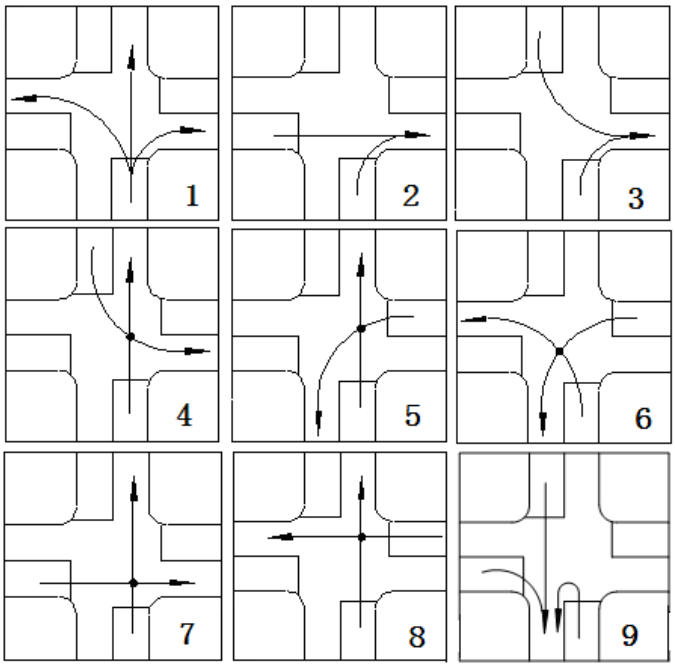

Figure 2 The Classification of Traffic Conflicts

(2) Quantitative identification of each class of conflicts

In order to determine the relative value of each type of conflicts shown in Figure 1 surveys had been conducted among drivers and traffic professionals. The value for conflict class 1 (diverge) was assumed to be 1 because it was thought to be the slighted conflict. The greater the value of C_n is, the higher the conflict intensity is. The values of different conflicts are shown in Figure 3.

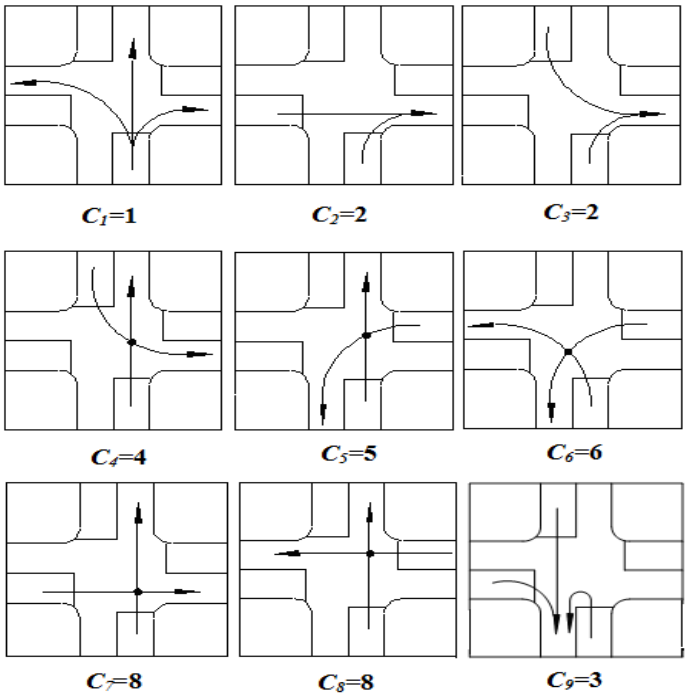

Figure 3 Values of Conflict Intensity for Different Classification of Conflict

CRITERION OF EVALUATION OF TRAFFIC ORGANIZATION

Once conflict complexity is estimated based on Equation 1 a question will be raised as how to evaluate the value of the conflict complexity. As introduced at the beginning of this paper there are three classes for evaluation conclusion for traffic organization of a proposed development. To obtain the threshold value of each class, 65 TIS reports of Beijing were reviewed and the results are shown in Table 2 and Figure 4, respectively(First, we estimated the smallest sample size according to the empirical formula, then decided to choice 65.).

Basing on the results of Figure 4, it is found that the values of conflict complexity are 90 at 15 percentile and 120 at 85 percentile, respectively. Therefore, the threshold value of conflict complexity is given as shown in Table 3.

Table 2 The Evaluation Conclusion of Various Proposed Projects

Evaluation Conclusion	Category	Number	Average value of conflict complexity C
Accepted	Residential	6	74
	Official	8	69
	Business	4	87
	Other	2	71
Needing	Residential	8	110
	Official	7	107

Improvement	Business	10	115
	Other	5	108
Rejected	Residential	3	129
	Official	5	131
	Business	6	139
	Other	1	133

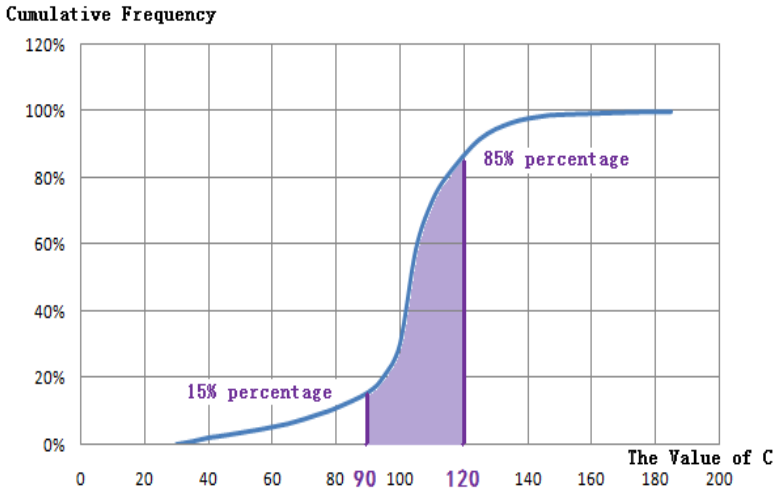

Figure 4 Cumulative Frequency Curve for Conflict Complexity

Table 3 Criterion for Evaluation Conclusion of Traffic Organization

Evaluation Conclusion	Accepted	Needing Improvement	Rejected
Value of C	≤90	90~120	>120

EVALUATION AND ANALYSIS SAMPLE

Take a proposed development as an example, this proposed development is about a Procuratorate Business Building in Beijing, which is in the northwest corner of Jianguomen bridge in Xicheng District. Now we take "conflict complexity" as a criterion to determine if the traffic organization of the proposed development meets the requirement from traffic conflict perspective.

There are two vehicle accesses within the study area. The north access forms a cross intersection with the direct connection road, and it has already eliminate almost all the traffic conflicts because of the signal control, so we needn't to evaluate the "conflict complexity" for this access. The south access forms a "T" intersection with the direct connection road as shown in Figure 5.

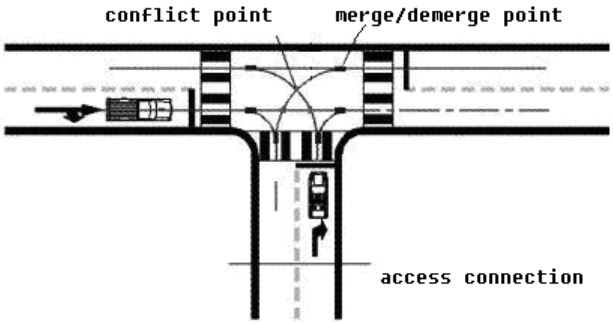

Figure 1 Traffic Organization of Access 2 in Corresponding Intersection

The distance from the south access to the nearest intersection around it is 40m. It is less than 50m, so the value of K in the model is 1.5. At the same time the south access has taken certain measures to separate vehicles, bicycles and pedestrians, and all the conflicts of vehicle-bicycle and vehicle-pedestrian have eliminated to a certain extent, so the value of λ_B and λ_P is 0. Then we can calculate that:

$$C = \sum_{1}^{m}\left[K(1+\lambda_B\delta_B)(1+\lambda_P\delta_P)\sum_{1}^{n}\sqrt{\frac{N_i+N_j}{2}}C_n \right]$$

$$= 1.5\times 1.41\times 24 = 50.8$$

Comparing the value with the evaluation criterion shown in the Table 3, we can know that the traffic organization plan is agreeable and the proposed development is acceptable from traffic organization perspective. But it is imperfect to make a judgement only by the single indicator in TIS, we should evaluate a traffic organization plan from other perspectives by different indicators, such as evaluating intersection load by load shock degree, evaluateing public transportation by transportation ability, evaluating traffic impact on environment by development satisfaction.

CONCLUSION AND FURTHER STUDY

The evaluation indicator of conflict complexity is proposed in this study to reflect the collision levels of traffic organization (or circulation) at site of proposed development. The purpose of proposing this indicator is to quantify the evaluation process of traffic organization, avoiding uncertainty in the evaluation of traffic organization plan. With this indicator transportation agencies can easily figure out if the traffic organization plan is agreeable with the criterion as indicated in Table 3 and determine if the proposed development is acceptable from traffic organization perspective.

It should be noted that this study is preliminary and leaves much to be improved. There are some limitations of the proposed methodology. For example, new developments often occur or involved mixed use districts not easily classified as residential, office, or commercial. Or that the reason traffic management issues are not classified in a single catch-all formula is because the issues are so site-specific and localized.

Since it is the first time to propose this single indicator to represent complicated conflicts, it's necessary to take on further study to tackle issues of each parameter in the model. The following explorations should be executed.

(1) Should the conflict complexity be the product of three different kinds of conflicts as recommended in this study or the addition of these three conflicts?

(2) The values of conflict intensity shown in Figure 3 are needed to conduct deep exploration.

(3) More samples from TIS should be analyzed to improve the threshold values for evaluation conclusion.

REFERENCE

[1] The Transportation Planners Council of The Institute of Transportation Engineers, "Traffic access and impact studies for site development", *ITE Journal*, 1988.

[2] Donald L.Wolfe. "Traffic Impact Analysis Report Guidelines". Los Angeles Department of Public Works, 1997.

[3] Beijing University of Technology (BJUT) "Report of Indicators and Standard Research on Traffic Impact Study of Projects in Beijing", Beijing Municipal Committee of Communications, 2008.

[4] Mohammed T. Mallah, Development of A Conflict Rate Prediction Model at Unsignalized Intersections, Dissertation Abstracts International, Volume: 64-12, 2003.

[5] Xing Ge, Jian Lu, Qiao-jun Xiang, Peng-ying Wang, "Study on Driving Behavior and Traffic Conflict at Highway Intersection", 2008 Workshop on Power Electronics and Intelligent Transportation System, 2008.

[6] Sihan Cheng, Yuelong Su, Danya Yao, A CA Model for Intrusion Conflicts Simulation in Vehicles-Bicycles Laminar Traffic Flow, 2008 IEEE Intelligent Vehicles Symposium Eindhoven University of Technology,2008.

[7] Beijing Municipal Institute of City Planning and Design (BMICPD), "Report of Traffic Impact Study", Urban Planning and Development, 2004.

[8] Beijing transportation Research Center, "Annual report of transportation development in Beijing of 2006", Journal of Traffic Engineering, 2006.

[9] X.M. Liu, and H.L. Duan, "Research on standard program of traffic conflict techniques at intersections", Journal of highway and transportation research and development, Vol.14, No.3,1997.