Al-Qadisiya Journal For Engineering Sciences, Vol. 5, No. 2, 150-165, Year 2012

STUDY OF TRAFFIC SAFETY EVALUATION AND IMPROVEMENTS AT UNSIGNALIZED INTERSECTIONS

Hameed Aswad Mohammed
Assistant Lecture
Engineering College / Al-Anbar University

ABSTRACT
Highway traffic safety is an important area in transportation engineering. Highway intersections are nodes of road networks and accident-prone locations. They are the places where vehicles coming from different approaches and moving towards different directions interact and conflict with each other. Due to the conflicts from all users, more traffic crashes could happen at unsignalized intersection as compared with roadway segments. Popular methods which are based upon traffic accidents and traffic conflicts are proved to be effective in certain circumstances, but difficulty in data collection of traffic crashes and subjective judgment and determination of traffic conflict constrain their applications. This paper introduces an approach to evaluate and improve unsignalized intersection safety performance. This method is fully based on the existing conditions of unsignalized intersection, including geometric design, sight distance, pavement surface conditions, traffic control devices, and lighting, etc. Different from the crash-based and conflict-based methods, this approach is a non-crash and non-conflict based analysis method. This approach needs to go through a field survey to unsignalized intersection to be evaluated. In this approach, a safety index is introduced to give a diagnostic summary of the safety performance degree of unsignalized intersections. Corresponding countermeasures are ranked and recommended based on the cost benefit analysis. In this paper, the approach (called diagnostic approach) is practically applied to evaluate and improve the safety performance of some unsignalized intersections in Fallujah city of Iraq.

KEYWORDS: Highway Safety, Unsignalized Intersection, Safety Evaluation, Safety Improvements

دراسة لتقييم وتحسين السلامة المرورية على التقاطعات بدون الإشارة الضوئية

حميد أسود محمد
مدرس مساعد / **كلية الهندسة**
جامعة الأنبار

الموجـــز
السلامة المرورية للطريق تكون المجال المهم في هندسة النقل.تقاطعات الطريق تكون بمثابة العقد في شبكة الطريق وتكون هي الأماكن المعرضة للحوادث.التقاطعات تكون هي المواقع حيث المركبات القادمة من مختلف المداخل والمتحركة نحو مختلف الاتجاهات المتداخلة والمتعارضة مع بعضها البعض.بسبب الحركات المرورية المتعارضة من قبل كل المستخدمين فأن كثير من حوادث الاصطدام سوف تحدث في التقاطعات بدون الإشارة الضوئية بالمقارنة مع مقاطع الطريق الأخرى.الطرق العامة التي تعتمد على بيانات الحوادث المرورية والحركات المرورية المتعارضة قد أثبتت بأنها تكون فعالة في ظروف معينة لكن الصعوبة تكون في جمع البيانات لحوادث الاصطدام المرورية والقرار الشخصي وأيضا في تحديد الحركات المرورية المتعارضة كل هذا يقيد تطبيق

هذه الطرق.هذا البحث يقدم طريقة لتقييم وتحسين أداء السلامة المرورية في التقاطعات بدون الإشارة الضوئية. هذه الطريقة تكون بالكامل معتمدة على الظروف الموجودة في التقاطعات بدون الإشارة الضوئية والتي تتضمن التصميم الهندسي،طبيعة سطح التبليط،وسائل السيطرة المرورية،والإنارة،... الخ.الاختلاف عن الطرق التي تعتمد على بيانات حوادث الاصطدام والحركات المتعارضة فان هذه الطريقة لاتعتمد على تحليل بيانات الحوادث المرورية والحركات المتعارضة.في هذه الطريقة يكون دليل السلامة قد ادخل لكي يعطي ملخص تشخيصي لدرجة أداء السلامة المرورية في التقاطعات بدون الإشارة الضوئية.التحسينات المطبقة على التقاطعات تكون مصنفة وكذلك التوصية تكون معتمدة على تحليل منفعة الكلفة. في هذا البحث تكون الطريقة (تدعى الطريقة التشخيصية) مطبقة عمليا لتقييم وتحسين أداء السلامة المرورية لبعض التقاطعات بدون الإشارة الضوئية في مدينة الفلوجة في العراق .

INTRODUCTION

With the rapid growth of the number of various vehicles, the ratio of the traffic accidents to vehicle number is increasing greatly. The road accident results in serious social problem and economic problem. Traffic safety is becoming more and more important for both drivers and the whole society [22]. Intersections are critical components of highway network and are used by all road users-passenger cars, heavy trucks, motorcycles, bicycles, and pedestrians. They are among the greatest safety challenges because they are some of the most common highway features, each having numerous conflict opportunities [6]. Unsignalized intersections with yield control or stop signs on the minor roads are one of the most common intersection types in the street system in Iraq [12]. Unsignalized intersections are of particular concern because there are so many of them on the highway system and because some experience sufficient number of particular crash types to indicate a need to improve safety. Good geometric design combined with good traffic control can result in an intersection that operates efficiently and safety [3]. Unsignalized intersections represent potential hazards not present signalized intersections because of the priority of movement on the main road [2]. The safety condition of intersection has a great influence on the traffic safety of the road network in the region. In order to improve the traffic safety of road net, and decrease the number of traffic accidents, it is necessary to reasonably evaluation the intersection safety conditions. There are mainly two types of intersection safety evaluation methods: one is direct evaluation which is based on the statistics of traffic accidents, the other is indirect evaluation which is based on traffic conflict technique [5]. Direct evaluation method mainly includes crash frequency, crash rate, crash severity, and crash statistic models. However, when these methods applied, the evaluation result's accuracy is affected because of long period and inaccuracy of statistical data. To accumulate intersection crash data could be a problem to many researchers, mainly due to the difficulty to obtain these data and the reliability of past crash data. The indirect evaluation method based on traffic conflict technique is a relatively new traffic safety evaluation method, which is mostly applied to evaluate intersection traffic safety by the ratio of conflict number and traffic flow [20]. Traffic conflict technique methods generally cover conflicting points, number of conflicts, conflict rate, conflict distribution, and conflict forecasting models [16]. However, this method also has shortcomings, such as the inaccuracy of the observed traffic conflicts numbers, and the lack of proper division of traffic conflicts according to different traffic conflicts various effects on traffic safety. The judgment and determination of traffic conflicts are more subjective nature. Different observers may give different traffic conflict judgments. In addition, Traffic conflict technique is a time consuming task. Although Traffic conflict technique has such problems, this technique method has been used by many researchers to analyze intersection traffic safety performance [17]. As discussed above, both crash-based and conflict-based safety analysis methods have some limitations in real applications. In the research presented in this paper, another approach called diagnostic approach was attempted. This approach is purely based on the existing intersection conditions, such as geometric, channelization, sight distance, pavement surface conditions, lighting, approaching traffic speed, etc. Different from the crash-based and conflict-based methods, this approach is a non-crash and non-conflict based analysis method. With such characteristics, this approach could give a relatively fast evaluation to intersection safety performance. In this approach, a safety index is introduced to give a diagnostic summary of the safety performance of an intersection [4]. Usually, non-crash and non-conflict based evaluation methods can give a safety evaluation to road facility with a relatively short time period and are relatively easy to be implemented in real applications. Particularly, this type of approach has advantages, such as low cost, high efficiency, and less time-consuming. Furthermore, this type of approach can be better used by field safety engineers to find potential safety problems and corresponding countermeasures can be implemented with short time period so that possible traffic safety problems can be prevented [4].

COLLISION AT UNSIGNALIZED INTERSECTION

Accidents caused by drivers who fail to stop are becoming increasingly frequent at unsignalized intersections on the state highway system. The major crash type unsignalized intersections is a right angle crash involving a vehicle entering the intersection from the stop approach and a vehicle on the through approach. A traffic crash occurring as a result of a driver disregarding a stop sign has the potential to be a severe collision since it typically involves a right angle type of impact “disregarding a stop sign “was listed as a contributing [3].

CAUSES OF TRAFFIC ACCIDENTS AT UNSIGNALIZED INTERSECTIONS

Causes of traffic accidents are rather complex, usually concerning several factors including human, vehicle, geometric design, and the environment. And the causes usually vary with the different characteristics of the different parts of highway system. Compared with roadway segments, intersections are characterized by the intensely concentrated intersections and conflicts of highway users from different approaches and towards different exists. It is almost always unavoidable that someone gets in the way of another one from time to time and the complicated maneuvers of turning left or right make such conflicts even more serious. Unfavorable human factors such as fatigue, inexperience, drunk driving and bad emotions, unfavorable environmental factors such as insufficient sight distance, slippery pavement and cloudy weather and unfavorable vehicle conditions might be combined to make such conflicts become traffic crashes. From the above discussion, it is easy to see that the essential causes of traffic accidents at highway intersection are the frequent interactions and conflicts among different highway users. Many other factors help to make some of the conflicts into traffic accidents. In fact, major safety improvement measures such as stop or yield, speed control, channelization, and lighting are mainly designed to mitigate or eradicate the interactions, conflicts, and accidents [15].

SELECTION OF EVALUTION METHOD

Traffic safety is influenced by lots of factors such as roadway geometric, road surface condition, traffic management and control, weather condition, driver behavior and so on. Considering data collection and processing, it is not feasible to identify all the factors, where only a few can be easily obtained and analyzed to estimate unsignalized intersection safety [1].

Diagnostic approach is used to evaluation unsignalized intersections safety performance which is based on the existing conditions that have direct relationships or impacts to traffic safety at unsignalized intersections [1].

METHODOLOGY

The evaluation method can be described by a flow process as shown in **Figure 1**. The following subsections give a brief description to each step shown in **Figure 1**. Potential safety problems are ranked according to the criteria such as the significance and severity. After safety problems with the highest ranks are identified, possible countermeasures are proposed and the cost-benefit analysis is performed to estimate the benefit-cost ratio for each countermeasures. Finally, corresponding countermeasures with the highest benefit-cost ratios are recommended to improve unsignalized intersection safety [4,9,10,13,18].

FIELD SURVEY FORM

For intersection safety diagnostic process, field surveys are necessary. Field engineers use the survey forms in the fields to perform diagnostic process by filling the survey forms (also called safety diagnostic forms) with information collected from each intersection. The basic information (elements) in the form covers intersection existing conditions that have direct relationships to traffic safety at intersections. Typical elements for unsignalized intersection include, but not limited to, geometric, channelization, sight distance, and pavement surface conditions, lighting, and approaching speed. Field engineers with check these elements at each intersection and they will give two scores to each element based on their personal judgments. One score is under the category of "significance" and the other one is under the category of "severity". The category of "significance" indicates whether the particular condition (such as lighting) at the intersection has significant safety problem with a score of "0" indicating not significant and "5" very significant, and the category of "severity" indicates whether the particular safety problem associated with the particular condition (such as lighting) would result in a severe traffic crash with a score of "0" indicating not severe and "5" very severe. **Table 1** presents the field survey form (safety diagnostic forms) with most existing conditions (elements) included. Field engineers need to fill scores for each element under the categories of “significance" and "severity". This form is relatively easy to be used in fields by an "average" field engineer [4, 10, and 13].

Selection of Intersection for Safety Evaluation

The process to determine the sites (intersections) in an area or roadway can be based on the past traffic crash history or a preliminary field safety survey. The number of sites for detailed field survey is really based on the budget limitations [4].

Identification of Safety Problems

Field surveyors need to use the survey form to survey each intersection. The survey items cover all related conditions. The surveyors need to use their field experience to judge the potential safety problems associated with the existing conditions at each intersection; filling in the diagnostic table mainly depend on the researcher's own practical experience, significance and severity evaluation criterions, which are established according on present criterions, guides practical experience and the expert's suggestion, the purpose is to provide a uniform reference of the safety problems to the researchers [9,10].

Ranking of Safety Problems

After completion of field survey and identification of intersection potential safety problems, the potential safety problems should be ranked. Some safety problems may be significant, but would not result in severe traffic crashes, and some safety problems may not be significant, but could result in severe traffic crashes. Thus, the indices "significance" and "severity" are used in ranking the potential safety problems. With the consideration of significance and severity, a safety index is introduced to rank a particular safety problem, such as non-sufficient sight distance for a given intersection. The safety index can be calculated by the following Equation [4, 10, 13, and 18]:

$$Ri = W1Ci + W2Si \qquad (1)$$

(i= 1, 2, 3…., n)

Where:

Ri= safety index for the ith safety problem,

W1= weight for significance index,

Ci= significance index for the ith safety problem,

W2= weight for severity index,

Si= severity index for the ith safety problem, and

n= number of the safety problems.

The safety index (Ri) represents the ranking of each particular safety problem, and if the (ith) particular safety problem has a large (Ri) value, this problem should have a higher rank for safety improvements. To use equation (1), the weights (parameters W1 and W2) should be estimated. In this research, the interview with experts was used to estimate the two parameters. With the data collected from the interviews, the final parameters are: W1=0.37 and W2=0.63, or Equation (1) has the following form:

$$Ri= 0.37Ci + 0.63Si \quad (2)$$

(i=1, 2, 3,…, n)

In order to rank intersections for safety improvements, the overall safety index (Y) for a particular intersection is used and described by Equation (3):

$$Y=\sum Ri \quad (3)$$

The overall safety index is the summary of the safety index for each particular potential safety problem. A larger (Y) value means the corresponding intersection has more significant and/or severe safety problems.

List Possible Safety Countermeasures

The selection of possible safety countermeasures should follow several principles such as (1) reduction of crash rate and crash severity, (2) reduction of the conflicts between non-motorized users and motorized vehicles, and (3) reduction of conflicts between vehicles. The selection of possible roadway safety countermeasures is relatively simple. Generally, one safety problem could have several countermeasures. On the other hand, one safety countermeasures could solve several safety problems. Many documents present potential roadway safety problems and corresponding possible safety countermeasures [10, 21].

Ranking of Possible safety countermeasures

Aiming at unsignalized intersection safety problems got from the field diagnosis, possible improving countermeasures are put forward from geometric design, management facilities, maintenance and other aspects. Many countermeasures to improve unsignalized intersection safety are difficult to be fulfilled because of shortage of fund, which leads to more traffic safety problems. Under this situation, it is necessary to offer some low cost, easy to operate countermeasures to solve the traffic safety problems. Comparing the countermeasures to improve the traffic safety, it can be found that they are different in cost and efficiency. Therefore it is necessary to make sort analysis among the improving countermeasures. It applies benefit cost ratio to rank and optimize the possible improving countermeasures:

$$BCR=B/C \quad (4)$$

Where:

B= Total benefit of the improving countermeasures,

C= Total cost of the improving countermeasures.

With the Equation (2), the engineers can get the order of all the possible improving countermeasures and choose the economical and feasible countermeasures.

(BCR) values can be used to rank possible safety countermeasures. The countermeasures with a larger (BCR) value should have higher priority (high rank) for implementation. In real application, due to the budget limitations, not all safety countermeasures will be implemented. Only the countermeasures with higher priority will be implemented [4, 10, 13, and 23].

Determination of Safety Countermeasures

Technically, the ranking of possible countermeasures can be used to determine safety countermeasure that will be implemented. In other words, Equation (4) or (5) is used to calculate the benefit-cost ratio for each possible safety countermeasure. If the implementation budget allows to the installation of countermeasures, the top countermeasures with the highest benefit-cost ratios will be selected for real implementation [4, 10, and 18].

APPLICATION OF CASE STUDY

There are many numbers of unsignalized intersections in Fallujah city. All the unsignalized intersections are in flat area and many of these intersections are controlled by police men or by signs and some of intersections are uncontrolled. Several of intersections are located in major arterials or in local roads and their main function is mobility. According to past crash data, the some of unsignalized intersections have a high annual crash rate. Site visits was conducted at most intersections to determine the intersection characteristics. These characteristics reviewed included traffic control, sight distances, pedestrian facilities, road surface condition, crosswalk facilities, geometric design, lighting, vehicle speeds, and on-street parking. This research has planned to evaluate and improve the safety performance of unsignalized intersections in Fallujah city. Therefore, there is a need to rank the safety problems at these intersections caused by existing conditions and rank the possible safety countermeasures. Based on field observations, there are some notices at unsignalized intersections in Fallujah city:

- With on-street parking close to the intersection approach, turning vehicles might have to stop if parallel parking maneuvers occur in the exit lanes, possible resulting in rear-end and side-swipe collisions. Vehicle entering and exiting the back lanes close to intersection also increase the collision risks.
- Lighting is not provided along the intersection approaches and at the most intersections may increase the frequency of collisions as night.
- Lack of visibility of traffic signs may contribute to crash experience at intersections. Visibility of traffic signs at intersections may be obstructed by physical objects (such as signs or other vehicles) or may be obstructed by weather conditions, such as fog or bright sunlight.
- Marked crosswalks are not provided across the legs of the intersections lead the pedestrians to use the roadway and increase the collision risks between pedestrian and vehicles.
- There is a lack of geometric design of some intersections.
- It was noted that the pavement surface of some intersections has distresses at different levels.
- Traffic conflict at the intersection is high, meaning traffic safety is not good.
- Several of intersections have limits the sight distances for some approaches.

Field survey was performed by several field engineers (surveyors) have sufficient safety and operational experience and were well trained in using the diagnostic survey forms. In the research, the diagnostic approach was applied to evaluate the safety performance of the intersections F1, F2, and F3 which are showed in **Figure 2**. **Tables 2** and **3** summarized the survey results (scores under the categories of " significance " and " severity ").According to the traffic safety problems ranking model (Equation 2), the total score and the order of traffic safety affecting degree can be gained. **Table 4** listed the safety problems and corresponding safety scores (which are the average scores from all surveyors) under the categories of “significance” and “severity ". In the same tables, the safety index for each safety problem identified by field surveyors is listed. Based on the safety index values shown in **Table 4**, the safety problems can be ranked. The ranking of the identified safety problems is also listed in **Table 4**.

After the safety problems were identified and ranked in the research, possibly safety countermeasures were proposed. Many low cost countermeasures focused on the intersection design and operation can be both implemented and effective at the local level. When improving an intersection consider some general strategies such as the following:

- Attempt to minimize intersection conflicts and crashes, and lessen the impacts of crashes when they do occur,
- Attempt to match a countermeasures to an identified safety problem,
- Evaluate implemented countermeasures to identify what works and what does not, for consideration at future locations, and
- Select countermeasures that are technically feasible and practical, and provide an advantageous benefit/cost ratio.

Practically, a safety problem may have several corresponding countermeasures and one countermeasure may be used to improve several safety problems.

The above describes a real application case with the use of the diagnostic approach developed in the research. It is found the approach is relatively easy to be used in fields. As shown in the real application, the approach has good applicability. To effectively use the approach, it is very important for field engineers to complete field surveys to intersections. Field engineers should have good field experience and safety judgments.

COUNTERMEASURES TO IMPROVE INTERSECTION SAFETY

Intersection crashes have many causes including, but not necessarily limited to, poor geometry and design, deficient operational control, insufficient maintenance, and human error. Considering all of these elements, the optimal approach to improve intersection safety is multidisciplinary in nature however, many low cost countermeasures focused on the intersection design and operation can be both implemented and effective at the local level [11]. The set of low cost countermeasures for unsignalized intersections is design to increase driver's alertness to the presence of the intersection and reduce potential conflicts with other entering vehicles. Countermeasures have been classified as basic or supplemental. Basic Countermeasures are those that are usually very low in unit cost and effective in term of reducing future crash potential [3]. There are a number of countermeasures that can be implemented to lessen the adverse effects of intersection hazards. The type of countermeasure depends on the nature of the intersection and the safety concerns apparent at a particular location [14]. The following methods were listed [3, 2, 7, 11, 16, and 17].

Provision of adequate sight distance

Provision of adequate sight distance on approach to and entering intersections, and when turning across oncoming traffic can reduce crash frequency and severity and studies have shown reduction of to 67 percent in crashes where obstructions that inhibited sight distance were removed [7]. Each unsignalized intersection contains several potential vehicle conflicts. The possibility of these conflicts actually occurring can be greatly reduced through provision of the proper intersection sight distance. Adequate sight distance for drivers at unsignalized approaches to intersections has long been recognized as among the most important factors contributing to overall safety [3]. Sight distance at intersection can be improved by clearing obstruction from the required clear zone envelop and more simply by prohibiting on-street parking near intersections and by moving stop lines further back from the intersection threshold [14].

Treatment to reduce speed

Given that speed and speeding is a major contributor to trauma at unsignalized intersections, measures to reduce speeds have great potential to minimize crash frequency and severity. There are a number of ways to manage speed on the approach to intersections including reduction of speed limits, provision of traffic calming measures such as pavement narrowing, installation of refuge islands, and alteration of the road surface (particularly raising of the surface, and provision of technologies to enhance speed limit compliance) [7, 9].

Improvement of intersection geometric design

Reduce the frequency and severity of intersection conflicts through geometric design improvements by provide left/right-turn lanes or offset left/right-turn lanes at intersection; provide by pass lanes on shoulders at T-intersections; provide full-length paved shoulders in intersection areas; restrict or eliminate turning maneuvers by signing, providing channelization, or closing media openings; convert offset T-intersections to 4-legged intersections; use indirect left-turn treatments to minimize conflicts at divided highway intersections, improve pedestrian motorcycle and bicycle facilities to reduce conflicts between motorists and non-motorists [2].

Provision of warning signs

These are provided to alert drivers of hazardous conditions that may not be apparent, such as the presence of intersections, particularly those with poor sight distance [8]. Call attention to the intersection by installing rumble strips on intersection approaches; provide dashed markings for major road continuity across the median opening at divided highway intersection; provide flashing beacons; provide variable message signs, provide pavement markings with supplementary messages, such as STOP AHEAD; and provide improved maintenance of stop signs [2].

Provision of lighting at unsignalized intersections

Adequate lighting at unsignalized intersection is required to increase visibility of the roadway and its immediate environment at night, thereby enabling drivers to maneuver safety and efficiently through an intersection; in their examination of the effect of installation of street lights at urban intersections on crash risk [7, 9].

Improve Management of Access near Unsignalized Intersections

Effective access management is a key to improving safety at and adjacent to unsignalized intersections. A key element of access management is closure or relocation of driveways adjacent to intersections. Access points within 75m upstream and downstream of an intersection are generally undesirable. Strategies for mitigating safety problems that may arise from a driveway located too close to an unsignalized intersection are to close the driveway (if other access to the adjacent property already exists) or to relocate the driveway (if no other appropriate access is available). When a driveway on a high-volume street adjacent to unsignalized intersection cannot be close or relocate, it may be appropriate to restrict turning maneuvers at the driveway [2].

Provide Skid Resistance in Intersection and on Approaches

Slippery Pavement should be addressed to reduce the potential for skidding. The coefficient of friction is most influenced by vehicle speed, vehicle tire condition, and surface condition. Consideration should be given to improving the pavement condition to provide good skid resistance, especially during wet weather. This can be accomplished by [2]:

- Providing adequate drainage
- Grooving existing pavement, and
- Overlaying existing pavement

Improve pedestrian, Motorcycle and Bicycle Facilities to Reduce Conflicts between Motorists and Nonmotorists

Improvements to pedestrian facilities that may reduce conflicts between motorists and nonmotorists include:

- Continuous sidewalks
- Signed and marked crosswalks
- Pedestrian signs and markings
- Sidewalk set-backs
- Pedestrian overpasses
- Median refuge areas

• Intersection lighting
Some of the problems that cyclists face at intersections include high traffic volumes and speeds and lack of space for cyclists. Possible improvement projects include:
• Widening the outside through lanes or adding bike lanes
• Providing median refuges at key minor- street crossings
• Providing independent cycle / pedestrian structures where necessary
• Providing smooth paved shoulders

Provide Signalized Intersections
Changing unsignalized intersections into signalized intersections and providing exclusive left-turn or right-turn lane and related signal phasing.

CONCLUSION

Intersections are important connections between two or more roadways and the resulting conflicting traffic movements make intersections crash-prone locations. The safety condition of unsignalized intersections has a great influence on the traffic safety of the road net, and decrease the number of traffic accidents.
Crash-based safety analysis is unpredictable and randomly happens and it is limited by locations and analysis time period. Thus, it needs a long time period to accumulate sufficient crash data and it is difficult to obtain these data and reliability of past data. Conflict-based safety analysis can be applied to quantitatively evaluate highway intersection traffic safety. The judgment and determination of traffic conflicts are more subjective nature. Different observers may give different traffic conflict judgments. In the research presented in this paper, another approach called diagnostic approach was attempted. In order to evaluate the safety performance of highway intersections more objectively, efficiently, and fast, the existing conditions at unsignalized intersection could be used as the basis for intersection safety performance evaluation.
Non-crash and non-conflict based evaluation method can give a safety evaluation to roadway facility with a relatively short time period and are relatively easy to be implemented in real applications. This type of approach can be better used by field safety engineers to find potential safety problems and corresponding countermeasures can be achieved with short time period. This research analyzes safety problem and present information on suggest effective, low-cost intersection countermeasures improvement at unsignalized intersections. These low-cost countermeasures can be applied to a large number of unsignalized intersections with a high frequency of crashes.

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Table 1 Survey Form for the Diagnostic Approach

Survey List	Survey Index									
	Significance					Severity				
	Low ↔ High					Low ↔ High				
	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5
1-Inadequate Lane Width										
2-Insufficient Intersection Sight Distance										
3-Complex Intersection Design										
4-Improper Traffic Signs as to Number, Size, Message, Placement, and Visibility										
5-Pavement Marking Faded and Poor Visibility										
6-Inadequate Curb Radius for Turning Vehicle										
7-Improper Pedestrian Crosswalk Placement and Design										
8-Vehicle Speed too High for Existing Condition										
9-Poor Pavement Skid Resistance										
10-Insufficient Lighting										

Table 2 Survey Result by Six Different Surveyors at Unsignalized Intersections of F1, F2, and F3 along Arterial Road

Period	Surveyor	Inadequate Lane Width		Insufficient Intersection Sight Distance		Improper Traffic Signs		Insufficient Lighting		Poor Pavement Skid Resistance	
		Significance	Severity	Significance	Severity	Significance	Severity	Significance	Severity	Significance	Severity
Time 1	A	3	4	4	4.8	2	2.9	4.2	4	2	3.5
	B	2.8	3.7	4.1	4.7	2.6	3	4.4	4.2	1.9	3.7
	C	3.1	4.2	4.2	4.6	3	3.1	4.7	4.3	2.1	3.9
	D	2.6	3.5	4.4	4.9	2.1	2.7	4.4	4.1	1.7	3.1
	E	3.2	4.1	4	5	2	2.5	4.6	4	2.4	3.6
	F	2.9	3.4	4.5	4.8	2.3	2.8	4.5	4.3	2.3	3.9
Time 2	A	2.8	3.9	4.1	4.8	2.2	2.9	4.1	4	1.8	3.3
	B	3.2	3.8	4	4.5	2.5	3	4.7	4.1	2.1	3.5
	C	2.7	3	4	4.7	2.8	3.1	4.5	4.2	2	3.9
	D	3	3.7	4.5	4.8	2.3	2.7	4	4	1.6	3.4
	E	2.9	4	4.2	4.7	2.4	2.8	4.8	4.3	2.2	3.7
	F	2.4	3	4.3	5	2	2.3	4.7	4.1	2.1	3.5
Time 3	A	3.1	4.1	4.3	4.8	2	2.4	4	4.5	2.3	3.6
	B	2.6	3.5	4.2	4.5	2.4	2.8	4.2	4.7	1.8	3.8
	C	2.8	3.9	4.3	4.8	2.9	3.2	4.5	4.1	2	3.7
	D	3	3.8	4.1	4.7	2.2	2.6	4.2	4.4	1.8	3.2
	E	2.7	3.9	4.3	4.8	2.1	2.5	4.3	4.6	2.1	3.4
	F	2.8	3.7	4	4.7	2	2.8	4.6	4.5	2	3.5

Table 3 Survey Result by Six Different Surveyors at Unsignalized Intersections of F1, F2, and F3 Along Arterial Road

Period	Surveyor	Inadequate Intersection Channelization		Pavement Marking faded and Poor Visibility		Inadequate Curb Radius for Turning Vehicle		Improper Pedestrian Crosswalk Placement and Design		Vehicle Speed too High for Existing Conditions	
		Significance	Severity	Significance	Severity	Significance	Severity	Significance	Severity	Significance	Severity
Time 1	A	3	3.2	1.7	2.5	2	1	2.2	1.2	3.2	4.5
	B	2.5	3	1	2.7	2.1	1.3	1.8	2	4	5
	C	2.9	3.1	1.6	3	1.4	1.1	2.5	1.5	3.5	4.1
	D	2.7	2.9	1.3	2.9	1.6	1.4	1.7	1.4	3.7	4.7
	E	3.2	3.4	1.4	3.2	1.7	1.6	2.8	1.8	3.2	4.9
	F	3.1	3.2	1.9	2.8	2	1	2.5	2	3.4	4.5
Time 2	A	3.2	3.6	1.7	2.6	1.9	1.3	2	1	3.6	4.4
	B	2.6	2.8	2.1	2.6	2.1	1.4	1.6	1.9	3.8	4.9
	C	2.5	2.9	1.6	3.1	2.2	1.7	2.3	1.8	3.7	4.3
	D	2.7	3	1.3	3	1.5	1.2	1.9	1.9	3.8	4.5
	E	3	3.1	1.4	3.4	1.9	1.6	2.2	1.5	3	4.7
	F	3.2	3.4	1.9	3	2	1.3	2.3	2.2	3.6	4.4
Time 3	A	3.1	3.5	1.7	2.8	2.2	1.1	2.1	1.4	3.4	4.6
	B	2.7	3	1.4	2.9	2	1.6	1.8	2.1	4.1	4.9
	C	3	3.2	1.6	3	1.9	1.8	2	1.7	3.7	4.3
	D	2.9	3.3	1.3	3.3	1.8	1.5	1.8	1.6	3.5	4.5
	E	2.9	3	1.4	3.2	2	1.8	2.1	1.7	3.1	4.5
	F	3.1	3.5	1.9	3.1	2.2	1.2	2.2	2	3.4	4.8

Table 4 Safety Problems and Corresponding Safety Scores for the Intersection of F1,F2, and F3

Problems	Average Score of Significance	Average Score of Severity	Total Scores	Rank
1-Insufficient Intersection Sight Distance	4.19	4.75	4.54	1
2-Insufficient Lighting	4.41	4.24	4.30	2
3-Vehicle Speed too High for Existing Condition	3.54	4.58	4.20	3
4-Inadequate Lane Width	2.87	3.73	3.41	4
5-Inadequate Intersection Channelization	2.91	3.17	3.07	5
6-Poor Pavement Skid Resistance	2.01	3.56	2.99	6
7-Improper Traffic Signs as to Number, Size, Message, Placement, and Visibility	2.32	2.78	2.61	7
8-Pavement Marking Faded and Poor Visibility	1.56	2.95	2.44	8
9-Improper Pedestrian Crosswalk Placement and Design	2.1	1.71	1.85	9
10-Inadequate Curb Radius for Turning Vehicle	1.91	1.38	1.57	10
Total			30.98	

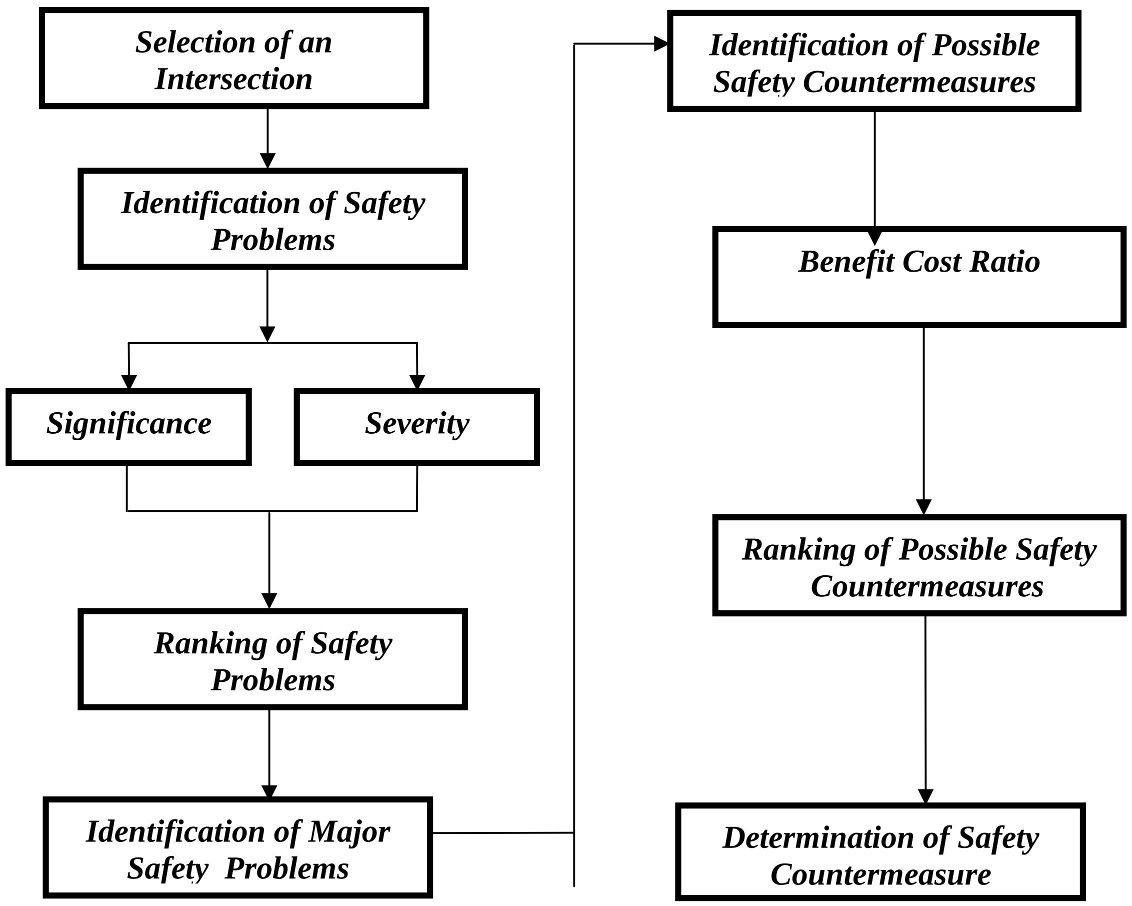

Figure 1 Flow Process of Evaluation Method

Figure 2 Satellite Image for Unsignalized Intersections in Fallujah City (**Google Earth 2011**)