A Conflict Index to Assess Traffic Safety at Intersections

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Abstract. In this paper, a conflicts-based technique, using an index measure is introduced to assess traffic safety at intersections. The technique helps in identifying sites most probable to profit from safety improvement as an alternative to crashes-based analyses. As a case study, the analysis and measure of safety for 11 four-leg signalized intersections at different sites in Baghdad city, have been done independently using direct methods based on crash rate and indirect methods based on the level of conflict risk measures. A comparison is achieved between the two methods and their outputs. The study results imply that a developed method of conflicts index of signalized intersections (CISI) (based on traffic conflict frequency and severity) could serve as a viable way of measuring the safety performance of signalized intersection at urban area. CISI can be established for existing conditions at intersections as well as in evaluating different design alternatives to more accurate safety comparison and better decision-making. Application of direct and indirect method results in identifying the same sites to profit from safety improvement. In addition, the research demonstrates a promising application of CISI in; relative comparison of conflict risk at various intersections and estimating conflict risk after potential countermeasures for before-after assessment of traffic safety at intersections.

1. Introduction
In the process of assessing traffic safety at intersection sites, there are two major approaches, crash-based safety analysis (direct methods) and non-crashes based analyses (indirect methods). The decision on which method to use for the identification of sites with potential for safety improvements is a major factor in terms of the effectiveness of road safety management process. The Highway Safety Manual (HSM) provides a set of thirteen crash-based performance measures that can be applied either isolated or in conjunction with the network screening process [1]. Performance measures in HSM require different data acquisition and modeling efforts from the safety analyst which may not be available especially in developing countries. However, the crash-based approach is set back by several shortcomings such as randomness and rarity of crash occurrence.

Traffic conflict technique (TCT) is one of the non-crash based analyses represents the indirect method to assess safety condition of intersection sites. Laureshyn and Varhelyi stated, if the goals are to make a safety diagnosis of a site, TCT is the right method for that [2]. TCT is based on the detection and count of "critical incidents" occurring in real traffic situations.

TCT can be estimated through traffic simulation or observed from real traffic condition by field observation on - site or assemble conflict events from videos. Many studies applied field observation and concluded that observed conflicts on a field in some comparative studies done are more valid than conflicts found by other procedures when denoting them to crashes.
2. Analyses and assessing safety based on traffic conflicts.

The events in the traffic environment occur at different levels. The ordering of traffic events by severity is defined by Hyden as shown in figure 1 in a “safety pyramid” [3].

![Safety Pyramid](image)

Figure 1. Safety Pyramid [3].

It is possible to group almost all of the operational definitions of the traffic conflict into two types: Evasive actions-based traffic conflict and temporal (and (or) spatial) proximity-based traffic conflict. Parker and Zegeer defined evasive actions-based traffic conflict as “…an event involving two or more road users, in which the action of one user causes the other user to make an evasive maneuver to avoid a collision” [4]. Hence, conflict according to that definition includes considerable judgment on conflict situation. Further, this definition infers that conflicts and crashes are of similar nature unless for the presence and the success of evasive action.

In a proximity-based traffic conflict, the critical events are recognized depending on temporal (and (or) spatial) proximity. It is defined as “…an observable situation in which two or more road users approach each other in space and time to such an extent that there is a risk of collision if their movements remain unchanged” [5]. The most common temporal proximity indicator family is Time to Collision (TTC) [6]. Specifically, a conflict was defined to be severe if the TTC value was less than the threshold of 1.5 sec. However, the threshold values vary in relevant studies from 1.0 to 5.0 sec.

A study conducted by Baker for investigating the relationship between crashes and traffic conflicts based on evasive action. The collected data confirm that conflicts and crashes are statistically associated [7]. Migletz carried out a conflicting study at 46 signalized and non-signalized intersections in the greater Kansas City area, the distinction of intersections by traffic volume (High, Medium and Low flow categories). The report concluded that it seems to be no observable advantage of using crash data compared to conflict data. Potentially, the combination of crash and conflict data could produce even better estimates (with lower variance) of the expected number of crashes compared to using only one data source [8]. Pietrzyk conducted comprehensive traffic conflict study by the center for urban transportation research. The study included a tabular form of observed conflicts, collected crash data and developed easy-to-use tables for Florida-based at different intersection types (4 and 3 legged signalized and unsignalized intersection). The number of lanes (instead of traffic volume) was used as an intersection classification parameter to reduce workloads in field data collection and to simplify tabulation [9].

A study conducted by Sayed and Zein described the application of traffic conflict technique to estimate traffic safety at intersections by using intersection conflict index (ICI) based on the level of conflict risk [10]. Table 1 presents the relative average conflicts risk associated with each grade of conflicts risk. Based on a study conducted Sayed and Zein, the conflict risk established ranges from LOSS A (low frequency and severity) through LOSS F (very high frequency and severity). The conflict risk, therefore, provides an indication regarding the relative risk of being involved in conflicts at intersections.

The established standards for traffic conflict frequency and severity for intersections allowing for relative comparison of conflict risk at various intersections. Further, Souleyrette and Hochstein conducted a study based on estimation conflicts (conflict frequency and severity) from simulation models and using them in assessment safety for different design alternatives [11].
Table 1. Conflict risk associated with ICI [10].

| Intersection conflict index | Conflict risk       |
|-----------------------------|--------------------|
| A                           | Negligible         |
| B                           | Low                |
| C                           | Moderate           |
| D                           | Moderate to high   |
| E                           | High               |
| F                           | Extreme            |

3. Analysis and Assessing Safety Based on Crash Rate (CR)
CR is one of thirteen tools used in HSM as a safety performance measure. CR is used as a tool to recognize and prioritize sites as in need of modifications and for appraisal of the effectiveness of treatments. In the HSM, CR is known as the number of crashes that happen at a given site during a certain time period in relation to a specific measure of exposure (e.g., per million entering vehicles (MEV) for an intersection).

4. Crash Modification Factor (CMF)
CMFs represent the relative change in safety due to a change in one specific condition (when all other conditions and site characteristics remain constant). Therefore, a CMF may serve as an estimate of the effect of a particular geometric design (add lanes or increase the width of the lanes) or traffic control feature or the effectiveness of a particular treatment or condition.

A list of CMFs for a variety of geometric and operational treatment types for urban signalized intersection, backed by robust scientific evidence available in HSM and other references like [12,13]. The CMFs in the HSM have been developed using high-quality before/after studies that account for regression to the mean.

5. Data collection and Methodology

5.1. Study sites
This study has been used 11 four-leg signalized intersection in the urban area of Baghdad city. Figure 2 shows the locations and names of intersections in the study sites.

5.2. Crash data
Crash data are collected for three years from 2015-2017 for 9 sites. No archived crash data are available at two sites. According to crash data there are 143 crashes occurred in 9 sites during 3 years, the average crashes for intersections was 5.29 crashes per year. Crash data in this study are represented for the crashes between vehicles only. The crash rate is estimated for each intersection by dividing the total number of crashes by MEV (total entering vehicles for major and minor streets) for the 3-year study period.

5.3. Geometric and Traffic Control data
Geometric and traffic control data needed in this study were collected from the field in each site in addition to the geometric layout of intersections and timing distribution of cycle length that obtained from relative authority (Mayoralty of Baghdad). Figure 3 presents a sample of the geometric design of Al-Masbah intersection (site No.7) in the study sites.

5.4. Traffic volume and conflict data
By the aid of positioning of surveillance cameras at each study site as well as field observation, necessary input data of traffic volume and conflicts was obtained. For each studied intersection, traffic volume and conflicts are observed for 16 hours on workdays (2 workdays for sites (1, 2, 3, 4, 5, 6 and 7) and 3 workdays for sites (8, 9, 10, and 11)). The hours of observation are distributed to cover morning, mid-morning, noon and evening periods for each workday.

| Site No | Intersection Name       |
|---------|-------------------------|
| 1       | Al-Muthanna             |
| 2       | AL-Saylow               |
| 3       | Al-Sakraha              |
| 4       | Beirut Square           |
| 5       | 14th Ramadan            |
| 6       | Aqaba ban Nafaa         |
| 7       | Al-Masbah               |
| 8       | Al-Sharika              |
| 9       | Al-Sarafya              |
| 10      | Academy of Arts         |
| 11      | Al-Jadyriah             |

**Figure 2.** Map of Selected Sites.

**Figure 3.** Geometric Layout of Al-Masbah Intersection (Site No.7).
5.4.1 Traffic volume
Two types of traffic volume measurements have been used: hourly traffic volume (HTV) and annual average daily traffic (AADT) for major and minor streets. Also, product of the hourly entrance volume (PEV) is used to represent the square root of HTV in thousand entering to intersection from major and minor streets. The AADT is estimated from account peak hour volume (PHV) for each site by using conversion factor (K) in HCM for the urbanized area to convert PHV to AADT. The AADT is calculated based on traffic survey in 2017, AADT for 2015 and 2016 which have been estimated based on used growth factor for traffic that has been obtained from relevant authority of urban transportation study in Baghdad city.

5.4.2 Conflict data
Conflict data are collected with the help of video recording equipment. In this study, conflict data observed for 20 minutes per hour from 16 hours of video recording, therefore, the total hour of conflicts observation used in this study is 5 hours and 20 minutes for each intersection. These period fulfills requirements reported by Glauz and Migletz that the minimum number of hours needed to estimate mean hourly count for major conflict data for signalized intersection should not less than 3 hours and 25 minutes as a period of observation per each site [14]. Two types of conflicts measures are collected; total conflict frequency and serious conflict frequency. Total conflict frequency is identified based on conflict risk and serious conflict frequency. Total conflict frequency is identified based on definition introduced by Parker and Zegeer while serious conflict frequency identified based in definitions introduced by Amundsen and Hydén using 1.5 sec as threshold values for TTC [4,5]. Further, Hourly Total Conflict (HTC) is used to represent the number of total conflicts frequency at a site divided by observation hours. On the other hand, Hourly Serious Conflict (HSC) represents the number of serious conflicts frequency (conflicts with TTC less than or equal 1.5 sec) at a site divided by observation hours.

5.5. Steps of Calculation the CISI and CMF
- Calculate PEV, HTC, and HSC according to definitions in 5.4.1 and 5.4.2. for each site.
- Calculate the CISI and identifies LOS of safety for sites under study based on conflict risk and accordingly construct scatter plot.
- Calculate the crash rate for sites and compare with the results of the CISI for most probable to profit from safety improvement.
- Further reviewed for hazard sites, select potential countermeasure, apply appropriate CMF and estimate CISI for hazard locations based on proposal treatments.

6. Analysis and Results
6.1. Safety Assessment due to CISI
According to scatter plot diagram of the (HTC/PEV) on the y-axis versus the (HSC/PEV) on the x-axis, CISI is identified based on the established a CISI region boundaries using one standard deviation from the calculated mean of the overall HTC/PEV and the HSC/PEV. The methodology used in this study to identify the CISI similar to the method established by Sayed and Zein, and has been applied in various research for safety improvement [11]. Based on certain measures of the CISI, the intersections introduce a quality scale for safety called the level of service of safety (LOSS). Figure 4 shows that, there are two sites with extreme conflict risk at LOSS F (site No. 6 and 7). These sites have the highest values of HTC/PEV and HSC/PEV across all sites under study. Seven sites have moderate conflict risk with LOSS C, but site No 8 has the highest values of HTC/PEV and HSC/PEV within this category and lay near the boundary of LOSS E. Site No.2 has the lowest value of conflict risk with LOSS A.

6.2. Safety Assessment due to Crash Rate
The proposed method in order to identify abnormal sites based on measure crash rate by using (mean plus one standard deviation) of a crash rate for sites, since in this study applied this method in the
construction of conflict risk for sites. The abnormal sites for crash rate method are site No. 6 and 7 since having crash rate value more than (mean+1Std.dev.) of intersection crash rates. Both methods used for safety analyses, crash-based methods and conflict–based method, concluded to the same result in identifying the most hazard locations.

6.3. Further review to improve extreme-risk sites
In this step, a further review of intersection characteristics (geometric layout and traffic control) is conducted for the two sites with extreme-risk according to the analyses above. Worthwhile, conflict rate (conflict per thousand vehicle passing) is estimated for two measures of conflicts for each approach. The aim of this step to identify which approach (or approaches) within an intersection may be causing in this deterioration in safety. Table 2 presents the three of CMF for four-leg signalized intersection in HSM, the CMF selected depending on deficiencies in sites and their corresponding of a higher value of conflict rate in approaches.

![Figure 4. Conflict index for signalized intersections](image)

**Table 2. CMF in HSM For four –leg signalized intersection**

| Treatment proposed        | Value of CMFs in HSM |
|---------------------------|-----------------------|
| Add left-turn lane        | $0.90^N$              |
| Add right-turn lane       | $0.96^N$              |
| Prohibit right-turn-on-red| $0.98^N$              |

$N$=number of approach
Table 3 presents a summary of geometric and operation feature related to potential countermeasure in addition to the value of traffic conflicts for 8 approaches for site No 6 and 7. This step shows that the deficiencies located in the intersection through investigating the conflict rate (conflict per thousand vehicle passing) for each approach and compared with the geometric features. Table 4 presents the countermeasures proposed for site No 6 and 7.

**Table 3.** Summary of geometric, operation feature, and conflict rate.

| Site No | Approach Direction | ELL<sup>a</sup> | ERL<sup>b</sup> | RTOR<sup>c</sup> | Conflict rate per 1000 vehicle (HTC/HTV) | Serious conflict rate per 1000 vehicle (HSC/HTV) |
|---------|-------------------|----------------|----------------|----------------|------------------------------------------|-----------------------------------------------|
| 6       | WB                | NP<sup>d</sup> | NP permitted   | 51.14          | 2.26                                     |
|         | NB                | P<sup>e</sup>  | NP permitted   | 38.95          | 2.14                                     |
|         | EB                | NP             | NP permitted   | 52.37          | 2.31                                     |
|         | SB                | P              | NP permitted   | 33.48          | 2.23                                     |
| 7       | WB                | P              | NP permitted   | 40.39          | 2.14                                     |
|         | NB                | NP             | NP permitted   | 48.28          | 2.15                                     |
|         | EB                | P              | NP permitted   | 46.33          | 2.25                                     |
|         | SB                | NP             | NP permitted   | 47.36          | 2.14                                     |

<sup>a</sup> Exclusive left-turn lane.

<sup>b</sup> Exclusive right-turn lane.

<sup>c</sup> Right turn on red.

<sup>d</sup> Provided.

<sup>e</sup> Not provided.

**Table 4.** Conflict index measures and LOSS for potential countermeasures

| Site No | Existing measures of conflict index | Potential Countermeasures | New measures of conflict index | New LOSS |
|---------|-------------------------------------|---------------------------|-------------------------------|----------|
|         | HTC/P EV                            |                           |                              |          |
|         | HSC/PE V                            |                           |                              |          |
| Proposal No 1 | 6 90.00 4.50 | Add left-turn lane at EB | 86.08 4.35 | E  |
| Proposal No 2 | 7 92.83 4.43 | Add right-turn lane at EB | 91.49 4.36 | F  |
| Proposal No 3 | 6 90.00 4.50 | Proposal no 1+ left-turn lane at approach | 83.52 4.235 | C |
|         | 7 92.83 4.43 | Proposal no 1 + left-turn lane at NB approach | 89.5 4.28 | E |
|         | 7 92.83 4.43 | Proposal no 1 + Proposal no 2 + left-turn lane at SB approach | 87.46 4.18 | C |

7. **Conclusion and Recommendation**

The objective of this paper is to identify potential hazards collision sites for a sample of 11 four-leg signalized intersections in urban area of Baghdad city through developing conflict index reflect the conflict risk as an alternative measure of crashes. Also, the study conducts a comparison between the
output of the developed method and the crashes-based method in; analyses, assessing safety and proposing the potential countermeasure to improve safety at hazard areas.

The results of this study have indicated the practical value of the TCT as a quantitative method for identifying safety problems at intersections. On-site conflict observation proved also useful for gaining a valuable understanding into the practical functioning of the different intersections, and the influence of other important factors on traffic safety. With regard to the consistency of the conflicts data (conflicts frequency and severity) and the historical crash data for the period 2015-2017 it can be said that there was a reasonable level of agreement for both methods used in this study.

Although a study with more intersections is required, the study results imply that the development method (CISI based on conflict risk) could serve as a viable way of measuring the safety performance of signalized intersection at urban area.

Validation of traffic conflicts against traffic crash data is a particularly difficult affair in case of limitations or unavailable of crash data. There is, however, a distinct need to develop valid and useful statistical predictive models (crashes-predication models) of the type suggested by Sayed and Zein [10].

The techniques mentioned in this research used as tools to support the effective decision. However, more studies required to explore the relation between the outputs of risk in site depending on unsafe events should be carried to explain findings and develop solutions to the problems in the future.

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