Coupling Visual Simulation Model (VISSIM) with Surrogate Safety Assessment Model (SSAM) to Evaluate Safety at Signalized Intersections.

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Abstract. Traffic safety is the main support of transportation engineering. Otherwise, there is no benefit to a facility that lacks safety. Despite that, most road engineers in developing countries ignore traffic safety in their designs or adopt traditional methods that suffer from data weakness. So there is an urgent need for surrogate measures more accurate from traditional methods. This paper offers an assessment of safety at signalized intersections in Hilla city's urban areas using a micro-simulation model (VISSM) coupled with the Surrogate Safety Assessment Model (SSAM). Three signalized intersections are modeled using the micro-simulation VISSM (version 10) model by calculating the traffic flows and speeds extracted from field data. Also, geometric characteristics and timing of the signal are simulated to reach the real-world. Then the vehicle trajectory files are exported to SSAM (version 3). Several indicators for traffic conflicts are computed by SSAM, involving the max speeding (Max S), the rate of deceleration (DR), the time of post encroachment (PET), and time to collision (TTC). The number, type, and severity of conflicts are calculated. The conflicts are categorized into three types according to the conflict's angle, rear-end, lane change, and crossing conflicts. The results showed that the optimal values for the two safety indicators at intersections differ from one location to another, where TTC values ranged between (1.5-1.8) s and PET (4.7-5.3) s. Rear-end conflicts prevailed in all sites until their reached 55% of all conflicts. The severity of the conflicts at approaches varied from 0.74 as a high-risk collision to 1.8 as a low-risk collision, while the (TTCI) values for 40 St and Bab Al Hussein intersections were 0.86 and 0.82 respectively. Therefore, they are both classified as high-risk intersections. As for the Bab Al-Mashed intersection (TTCI=1.23), it is classified as moderate risk.

Keywords: Traffic Safety, SSAM, Micro- Simulation, VISSIM, Severity of conflicts, high-risk

1. Introduction
Traffic safety is a top priority of transportation projects. The design, planning, and maintenance of transportation facilities must consider the impact of crashes on designing or assessing alternative designs [1] because crashes are the direct traffic safety measurement. Studying an alternative measure for assessing the safety status would give traffic engineers a clear safety vision in the present and the future.

According to World Health Organization (WHO)[2], more than 1,350,000 people die every year due to crashes and more than 50 million people suffer from disabilities that may not improve. All efforts
must be combined, especially traffic engineers, to prevent deaths resulting from crashes, of which part may be under our control.

Researchers are searching for alternative approaches as the simulation technique for determining road safety because collisions are often fatal incidents, and thus it is impossible to remain with random conventional techniques of study of traffic crashes. For testing the safety levels of current and new infrastructures, microscopic simulation models can be observed as promising systems [3]. The software developed using the FHWA [Surrogate Safety Assessment Model (SSAM)], which automates conflict analysis by manipulating the vehicle trajectories generated throughout the simulation, is the core of this strategy.

1.1. Facts & Numbers About Traffic Safety In Iraq
Wars and terrorism are not the only these harvesting Iraqi lives. In Iraq, all paths (paths do not mean road, street) lead to death. Traffic crashes in Iraq have become one of the biggest daily fears that threaten the citizens' lives after the violent acts and deadly diseases that killed Iraqis after 2003; safety on roads is the main issue in Iraq. The Central Bureau of Statistics implements an annual report on traffic crashes recorded in police stations in all governorates except the Kurdistan region[4].

The most important indicators about traffic safety for 2019:

1.1.1. At the level of Iraq
- The number of traffic crashes recorded was (10753), of which (2629) were fatal crashes and non-fatal crashes were (8124).
- Crash accidents recorded the highest percentage with (52.7%) of the total accidents.

1.1.2. At the level of Hilla city
- The percentage of deaths (18.5%) and injuries (81.5%) is recorded from 2014 until 2019.
- The traffic crashes in Hilla city are 329 out of 1127 crashes in Babil Governorate, distributed to five districts during the specified period. Figure 1 shows the share of each district.

![Figure 1. Percentile share of traffic crashes at each district in Babil Governorate.](image)

The statistics indicate high rates of crashes that require reducing their occurrence. One way to reduce it is to take an optimal approach based on an efficient assessment of the traffic system's safety conditions.

1.2. Study Objectives
The study aims to evaluate signalized intersection through a simulation-based approach by VISSIM software and the Surrogate Safety Assessment Model (SSAM) to simulate the conflicts between vehicles and, therefore, better understand traffic causes crashes enhancing traffic safety. By identified the following goals:
• Determine if SSAM and VISSIM can provide a reasonable estimation for traffic conflicts at the signalized intersections.
• Determine the optimum thresholds used in estimating conflicts for the two main safety indicators TTC and PET.
• Modeling the Real-world of studied intersections using micro-simulation software VISSIM.
• Determine the number of conflicts and the predominant conflict type in each approach for the intersection.
• For determining the most dangerous approach of the conflicts and classification severity intersection in terms of severity risk.

2. Literature Review

In general, few Iraqi researchers are interested in traffic safety. (R. Z. Majeed & H. A. Ewadh) 2019 studied traffic safety assessment at nine signalized intersections in Baghdad city in two ways. The first was based on Highway Safety Manual using three methods (Empirical Bayes, crash rate, and crash frequency). While (conflicts rate and Conflicts frequency) were applied in a second was based on conflict. The study showed that the dangerous conflict frequency in conflict-based methods perfected than the crash frequency method. So, the dangerous conflict frequency maybe serves as an applicable option for safety performance evaluation.

The thought of using the micro-simulation modeling for road safety assessment appears to be attributable at first to Archer (2000) after progress in techniques. Archer declared the key to these tools’ success for assessing safety lies in the ability to model at a level similar to the real-world.

Fan et al.2013 [6] used VISSIM and SSAM software for estimating the traffic conflicts by field measure at freeway merge zones. The conflicts in the field-collected manually, and conflicts have been compared with simulated conflicts. The outcomes showed a sensible consistency between the observed conflicts and the simulated.

Guo et al.2019 [7] investigate the relationship between field-measured conflicts and simulated conflicts, estimated from the (SSAM) for two signalized intersections in Brisbane city of Australia. The study results indicated a good connection between field-measured and simulated conflicts, particularly at the higher for (TTC) thresholds.

Muley et al.2018 [8] use the micro-simulation environment to foresee vehicle & vehicle and between the vehicle-pedestrian conflicts at Doha signalized intersections in Qatar's country. The real-world conflicts were observed simultaneously with traffic and pedestrian data. The studied intersections are then modeled using the VISSIM micro-simulation tool, where vehicles and pedestrian trajectories were created. Then (SSAM) was used to analyze the simulated to identify conflicts within the study zones. The results displayed that conflict could be reasonably surmised. Further, the micro-simulation approach can be used to foresee potential conflicts during scenario testing, and the outcomes can be identified to assess the effect of the geometric improvement in decreasing the potential conflicts.

Molan et al.2021 [9] studied safety assessment by using the VISSIM simulation model and the surrogate safety assessment model SSAM at new offset diamond interchange (ODI) instead of the traditional interchange due to its failure. based on the results, the (ODI) showed the possibility to be a successful alternative and favorable design in the terms of safety.

Cruz et al.2021[10] presented their paper that includes a study of traffic safety in two roundabouts using a simulation approach. In this paper shows the results of a comparative safety assessment between the proposed basic turbo-roundabout and existent two-lane roundabout, they're designed for the same intersection, to define the best of the two from a safety perspective, depending on surrogate safety measures and traffic conflict through the micro-simulation model (VISSIM) and SSAM.
software to identify six surrogate measures. The number of conflicts was found (72%) fewer at the turbo-roundabout and found that traffic conflict at the turbo-roundabout in a form cluster group, while conflict at the roundabout is scattered.

2.1. The Concept Of Safety Pyramid
In 1987 Hyden proposed a safety pyramid, or it is sometimes called the Hyden pyramid, which comprises different levels for all the potential interaction events created within any vehicular flow. Figure 2. illustrates the connection between the severity of the event and the probability that it will occur and indicates the most probable events are less serious ones, while less probable events are the most serious. According to this approach, the hierarchy of safety was divided into three parts, as shown below:

- **Pyramid Base**: represents extremely safe traffic events and vehicle interactions undisturbed.
- **Pyramid Mid**: conflicts may exceed the potential of occurrence but sometimes surpassing even the slight conflicts to be severe.
- **Pyramid Top**: represent dangerous events, and the severity ranges from damage to injuries and may be fatal in some cases.

![Figure 2. Hyden’s Safety Pyramid.](image)

After creating the trajectory file with a micro-simulation VISSIM and exporting the file to SSAM, SSAM analyzes the file and calculates both TTC and PET.

2.2. Data Collection
2.3. Study Area
Intersections have always been a source of great concern to their users since these are weakness sites from the perspective of traffic safety because the frequent traffic crashes that occur at intersections due to multiple conflicts between vehicles. Therefore, The study area was chosen at intersections in the urban areas of Al-Hilla, the center of Babel Governorate. The study included three signalized intersections. Figure 3 clarifies the study area.

![Figure 3. Intersections' locations dropped onto Google Map image.](image)
2.4. Sources of Data
The accuracy of the results through which the traffic engineer can assess traffic facilities' safety depends on the scanning data accuracy, especially in the micro-simulation approach where extreme accuracy is required to represent the studied sites' real world. Thus, creating a trajectory file in a way that simulates the reality of the site to the degree of conformity so that can get logical results by SSAM Software analyses. The collected data were divided into four sections.

- Traffic data (traffic volumes, speeds).
- Traffic conflict data.
- Geometric characteristics data.
- Crash data.

The essential input source for the VISSIM micro-simulation and is in the first and second data collection stages. Simultaneously, the same values are used in the field analysis and the third stage data, which is the basis of the field study, while the data of the fourth stage lacks accuracy and weakness. These data were collected as information that enriches the reader, even if it is inaccurate and nothing else.

2.4.1. Traffic Data
The data include the number of vehicles turning to the left, right, and moving on each intersection approach. Four cameras were used on each side to cover the entire intersection, and each camera recorded videos for 8 hr. on two consecutive days. The data collection period continued through November and December 2020. Table 1 shows the dates of the video recordings and peak hours.

Table 1. Time and peak hours during the video record at the studied intersections.

| Intersection Name    | Date       | Start Time | End Time | Peak hour   |
|----------------------|------------|------------|----------|-------------|
| Bab-AL Mashed        | Nov.22th,2020* | 8:30      | 10:30    | 8:30-9:30   |
|                      | Nov.23th,2020 | 8:30      | 10:30    | 8:30-9:30   |

| Bab-AL Hussein       | Dec.6th,2020*  | 8:00      | 10:00    | 8:00-9:00   |
|                      | Dec.7th,2020   | 12:00     | 14:00    | 8:00-9:00   |

*Peak day

Figure 4 shows the traffic volumes at the peak hour volume with a screenshot of video recordings used at the 40 St. intersection.
2.5. The software used in the study

In the last decade, increased use of traffic simulation models due to the massive development of computer software contributed to simulation models' development. All traffic simulation models including VISSIM do not measure traffic safety measures, but it needs support from the surrogate safety assessment model SSAM.

2.5.1. VISSIM micro-simulation Software

VISSIM is a microscopic multi-modal traffic flow simulation software package developed by PTV Planung Transport Verkehr AG at the University of Karlsruhe in Germany. It was initially designed to simulate traffic in cities. The meaning in German is (Verkehr in Städten – Simulations Modell), but mode for freeway simulation is also added later. The latest update of the software allows pedestrian flows besides private transportation. It can also model rail public transportation.

Platform (PTV VISSIM, 2020, Student version) was used in this research to simulate the traffic interaction. According to the PTV VISSIM user manual, Traffic flow is computer-generated under different constraints such as signal control, vehicle composition, lane distribution. The major advantage of VISSIM over other programs is its flexibility. The VISSIM micro-simulation platform allows a small-time step of 0.1 seconds that provides high accuracy for simulation, thus give detailed vehicle interactions. Also, Entries of all (traffic, geometric) data that specify from the user to reach the studied sites' real reality.

The VISSIM idea is based on whether the driver could be in one of four modes of driving [11]: approaching, free driving, following, or braking. Principally, the software is suitable for traffic engineers.

2.5.2. SSAM Software

The Federal Highway Administration (FHWA) developed a software application called the Surrogate Safety Assessment Model (SSAM) to conduct a statistical study of traffic flow data created from the microscopic traffic numerical simulation. [12]. SSAM reads simulation software-generated trajectory files and calculates protection surrogate steps. The program's algorithm and logic were based on 2003 research performed by Gettman and Head [13]. This methodology avoids the subjectivity involved with the traditional method of conflict analysis.

Using simulation software and SSAM consumes less time than other traditional safety analysis methods that a long wait time for data collection. SSAM can classify conflicts according to the conflict angle that SSAM extracts from path files constructed using the VISSIM for each pair of conflicting vehicles (Pu & Joshi, 2008). SSAM calculates the number and severity of conflicts. The conflict is classified into (Crossing, Rear end, Lane change, Unclassified).

Figure 4. The Stage of Collecting Traffic Data.
SSAM featured are summarized below[14]:

- Provide tools for traffic engineers to perform flexible safety analysis.
- Compatible with as many traffic simulation models as possible.
- Use the best possible surrogate measures (i.e., most representative of crash propensity).

3. Methodology

In addition to operational requirements, the signalized intersections must operate safely. Intersections frame a short section of the transportation system infrastructure. However, crashes inside intersections are considered high. Collected data from various sources were analyzed using the micro-simulation technique in conjunction with the surrogate safety assessment model SSAM. Figure 5 displays a conflict table in which each row representing a conflict and each column representing a specific description of that conflict.

![Figure 5](image)

**Figure 5.** Details of each conflict extracted by SSAM Software.

In this paper, several surrogate safety measures were computed. Among the most famous of these indicators are the time of collision TTC and the Post-Encroachment Time PET. TTC defined as the expected time to occurrence collision between two vehicles if both vehicles stay in the same direction and maintain their speed unchanged. While PET defined as the time difference between the first vehicle passes at the intersection point to the moment that which the second vehicle passes at the same point. The conflicts number in the three sites was counted; each type's classification and severity were determined through a series of steps shown below.

Step 1
Determining sites through the user interface of the VISSIM software connected to the network through the street map contributions, this link between VISSIM and street maps from Google Map is very important to increase the accuracy in determining the geometric properties of the site beside Captured data from the field.

Step 2
After Quick show of the most important phases for modeling sites to getting correct simulation close to real-world.
- Identify the basic simulation parameters such as The simulation time of 3600 s, representing a peak hour. The number of simulations was set at 10 runs with Random seeds identified at 10 seeds, The Simulation resolution, which defines how repeatedly vehicle locations are re-calculated at one-second simulation, was identified in 10 places.
• Creating the network through links and connectors and identify the number and width of lane for each link.
• Defining compositions of the vehicles, vehicle inputs, desired speed distribution, vehicle routes.
• Identify the conflict area and the rule of priority. Create traffic signal and setting stop line.

After modeling intersections, the simulation model was run several times. The purpose of duplicating the simulation to obtain statistically sufficient data. The simulated path files are saved in trj format. Trj file contains information about simulation trajectory such as (speeds, coordinates, time, etc.). Trajectory file can only create through simulation run. Figure 6 briefly illustrates the intersection modeling steps.

![Figure 6](image.png)

**Figure 6.** The Modeling Stages at 40 St. Intersection.

**Step 3**

Before trj file generated from the VISSIM simulation model is analyzed by SSAM to extract the conflicts properties. Optimal values for main safety indicators (TTC and PET) should be found. SSAM uses default values ($TTC=1.5$) and ($PET=5$) seconds based on previous research studies (Gettman and Head 2003) and can be changed by the user to obtain optimal values for the studied site. Moreover, that done through the feature available (Specify the number of threads) in SSAM by setting several thresholds for TTC indicator only at the first stage at each threshold the number of conflicts is calculated to extract the optimum value TTC. Several PET thresholds are set jointly with the optimum TTC value in the second stage to obtain the optimum PET value. Figure 7 shows the relationship between indicators values and the total number of conflicts.

![Figure 7](image.png)

**Figure 7.** Optimum values of TTC and PET at 40 St. Intersection
4. Results
After determining the optimal TTC and PET indicators at 1.5 and 4.7, respectively. SSAM analyzes vehicles’ TRJ file as shown in table 2, which shows a sample of the total conflict value that equals =81 conflicts for analyzing one simulation run for 40 St. Intersection.

Table 2. Sample of SSAM outputs at 40 St. Intersection.

| TRJ File | TTC   | PET   | Max. S | Delta S | DR    | Max. D | Max Delta V | Conflict Angle | Clock Angle | Conflict Type |
|----------|-------|-------|--------|---------|-------|--------|-------------|----------------|-------------|---------------|
| 40-trj   | 1.40  | 2.90  | 6.48   | 6.48    | -2.73 | -3.16  | 3.24        | 0.00           | 5:59        | RE            |
| 40-trj   | 0.60  | 0.70  | 1.83   | 1.66    | -7.88 | -7.88  | 1.31        | 63.21          | 3:54        | LC            |
| 40-trj   | 0.70  | 1.00  | 5.13   | 2.29    | -7.24 | -7.34  | 1.15        | -25.13         | 6:50        | LC            |
| 40-trj   | 0.30  | 0.60  | 5.63   | 1.75    | -7.12 | -7.20  | 0.91        | 18.07          | 5:24        | LC            |
| 40-trj   | 1.50  | 1.70  | 5.36   | 3.75    | -7.01 | -7.01  | 2.05        | 0.00           | 6:00        | RE            |
| 40-trj   | 1.40  | 2.00  | 4.84   | 1.38    | -0.20 | -2.81  | 0.75        | 0.00           | 6:00        | RE            |
| 40-trj   | 1.10  | 1.10  | 7.45   | 8.22    | -0.01 | -0.01  | 4.11        | -82.07         | 8:44        | C             |
| 40-trj   | 1.20  | 1.90  | 5.77   | 5.01    | -0.07 | -6.38  | 2.68        | -0.06          | 6:00        | RE            |
| 40-trj   | 1.40  | 1.20  | 3.46   | 3.27    | -0.45 | -1.82  | 1.87        | 16.87          | 5:26        | LC            |
| 40-trj   | 0.30  | 1.00  | 5.92   | 2.19    | -7.92 | -8.07  | 1.22        | -20.64         | 6:41        | LC            |
| 40-trj   | 1.50  | 3.50  | 1.20   | 1.20    | 0.00  | 0.00   | 0.63        | -15.46         | 6:31        | RE            |
| 40-trj   | 1.30  | 4.30  | 1.48   | 0.50    | -0.14 | -7.59  | 0.26        | 0.00           | 6:00        | RE            |

Rear End= RE, Lane Change= LC, Crossing= C

SSAM provides statistical values of the (min., max., mean, and variance) of SSAM measures (TTC, PET, MaxS, DeltaS, DR, MaxD, Max DeltaV) as shown in figure 10. Also, figure 8 shows a summary of the total number of conflicts and the number of each of their types. SSAM software, depending on classifying conflicts on the angle of conflict, follows:

- $|\text{conflict angle}| > 85^\circ$ the conflict is classified Crossing.
- $|\text{conflict angle}| < 30^\circ$ the conflict is classified Rear-end.
- $30^\circ \leq |\text{conflict angle}| \leq 85^\circ$ the conflict is classified Lane-change.
- Conflict angle unknown the conflict is considered Unclassified.

Figure 8. A summary of statistical data for safety indicators at 40 St. Intersection.
Conflicts for each approach were identified by the link list that exists in the filter tab. Filter links contain an equal number of links created within the VISSIM simulation model. This feature allows SSAM to show the results of conflicts for the entire site this is done by choosing a command all. It is also possible to display result of separate part of the site for one or more links (links at intersections mean intersections approaches) by selecting the number of the approach link. Table 3 shows the (total conflicts, the number of each conflict type, and severity of conflicts ) of each approach for selected sites for ten randomly simulated.

| Intersection Name | APP. (No. of Conflict / hr) | THTC_{APP} | TTC_{APP} | ROCR_{APP} | THTC₁ | TTC₁ | ROCR₁ |
|-------------------|----------------------------|------------|----------|------------|-------|------|-------|
|                   | RE | LC | C |                 |           |       |       |       |       |       |       |       |
| 40 St.            | NB | 12 | 8 | 3             | 23        | 0.80  | HR    |       |       |       |       |       |
|                   | EB | 5  | 6 | 3             | 14        | 1.03  | MR    |       |       |       |       |       |
|                   | SB | 11 | 6 | 2             | 19        | 0.93  | HR    |       |       |       |       |       |
|                   | WB | 15 | 7 | 3             | 25        | 0.77  | HR    |       |       |       |       |       |
|                   | NB | 12 | 8 | 3             | 24        | 0.92  | HR    |       |       |       |       |       |
| Bab-Al Mashed     | EB | 5  | 3 | 1             | 9         | 1.47  | MR    |       |       |       |       |       |
|                   | SB | 10 | 7 | 3             | 20        | 0.98  | HR    |       |       |       |       |
|                   | WB | 3  | 0 | 1             | 4         | 1.8   | LR    |       |       |       |       |       |
| Bab-Al Hussein    | EB | 19 | 10| 4            | 33        | 0.74  | HR    |       |       |       |       |       |
|                   | NB | 16 | 8 | 2             | 26        | 0.77  | HR    |       |       |       |       |       |
|                   | WB | 9  | 4 | 1             | 14        | 1.11  | LR    |       |       |       |       |       |

THTC_{APP}: Total hourly traffic conflicts at approach. THTC₁: Total hourly traffic conflicts at intersection, ROCR_{APP}: Risk of collision rating at approach (HR: High risk (0< TTC <1), MR: Moderate risk (1< TTC <1.5), LR: Low risk(1.5< TTC <2)) Sayed & Zain [15].

5. Conclusions and Recommendations
   - Rear-end conflicts prevailed at all intersections until they reached 60% of the total conflicts at Bab- Al Hussein intersection.
   - The severity of conflicts for all intersection approaches ranged from 0.74, indicating a high risk, even up to 1.8, which refers to low risk.
   - The intersections of 40 St. and Bab Al Hussein were classified as high-risk intersections, while the Bab Al-Mashed intersection was classified as a moderate-risk intersection.

In general, further studies must improve safety in all traffic facilities for enabling drivers to avoid crashes in addition to the following recommendations.

- Provide pavements with a higher skid resistance in the intersection could be a positive contribution to achieve safety. Sometimes the driver may have to brake hard.
- Implement periodic and programmed maintenance of intersection approaches and traffic
- Provide clear sight at intersections and improve visibility of signals using mast arms to enhance the pre-warning and remove visual "noise" (e.g., with advertising signs) that contribute to crashes.
- Avoidance of the use of narrow lanes at intersections and eliminate parking on intersection approaches.
- They cooperated with international institutions specializing in safety and traffic to benefit from their experience in this field, such as the International Federation of Associations for the Prevention of Road Accidents (PRI).
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