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Evaluation of Safety Performance Functions by AIMSUN Micro-Simulation Model

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Abstract

Traffic safety in different transportation system as one of the major issues which have been considered by experts in this field and conducted research in research years in this section shows that the main difficulty in the separation field of safe transportation from non-secure transportation is impossibility to provide a comprehensive and extensible model for each system by using common models. By developing traffic simulation software in the last 2 decades, the orientation of these studies is from evaluating the safety performance functions associated with the rate and accident severity to providing alternative measures of safety performance based on the obtained results from modified micro-simulation models. The base of forming and defining these criteria is to evaluate the issue with the ongoing interaction approach and expected behavior of drivers before the traffic collisions in the mainstream.

Keywords: AIMSUN, Numerical model, Safety performance, Micro simulation

1. Introduction

22 Bahman Square located in Qazvin is the selected case study in this research simulation software. Thus, by using the information of vehicle trajectory during 0.1 second intervals and writing the computational algorithm related to 3 proposed performance criteria, various interactions between vehicles have been evaluated. To confirm the effectiveness of safety measures, the ANOVA for three various traffic parameter are: A) Taxi percent of all automobiles, B) total incoming traffic volume to model and C) percent of left turn movements which is done for safety performance criteria such as DRAC, TTC, and CPI. The results indicate that the applied model is practical and it is reliable in the intra-automobile interactions modeling in signalized intersections. So the reduction of average speed of automobiles within the transition zone and output approaches and circulation sections around the central square island, particularly in the squares with an elliptical geometry cause disturbances in traffic flow and increasing the probability of risky behaviors from backwards. In total, from 3 safety performance criteria, the DRAC criteria can describe the likely situations for backward collisions between automobiles for different traffic characteristics in the rotation squares of signalized square.

The safety of transportation systems as one of the major issues that is linked to public health of roads users, directly is considered by experts in this field of research and conducted researches in this area in recent years in this section, and it show that the major problem in the field of separation the secure transportation facilities of non-secure, is the impossibility of providing a comprehensive and extensible model for each system by using common models, particularly the accident prediction models by using the recorded accidents data [1]. In fact, due to the completely random nature of events that leads to accident and the variety of geometric and traffic designs of different transport systems, the use of these models without calibration of main defined parameters in the local conditions do not provide correct results [2]. In addition to validating these models, we require extensive field studies on a large number of similar systems that this issue requires educated expert forces to gathering and fixing the correct information to create a comprehensive database for analyzing and evaluating the process. Among them, signalized squares is one of the particular transformation systems in spite of studies before and after traffic performance evaluation in terms of capacity and delays on vehicles in comparison with other types of junctions are neglected in most countries due to the lack of sufficient information about safety performance. And based on these criteria to identify safety performance criteria, measuring and analyzing them is a research filed need further study.

In general, the safety performance criteria which are known as safety indicators or safety alternative criteria indicate the type and intensity of intra-automobile interaction which is related to the pre-predicted hit point. These criteria are defined based on pairwise characteristics of vehicles velocity and spatial distances. The main hypothesis in conducting these criteria is that if there is possibility to identify the hazardous situations which are considerably occur with a high frequency rather than accidents, in this case the valid statistical results can be obtained without the need for the recorded data of accidents. In addition, the use of safety performance criteria with respect to the precautionary approach before the accident occurrence in safety studies, provide the ability to identify the safety problems before accidents and incidents [3,4].

Time to Collision (TTC) of a moving object in one direction can be calculated continuously over time. Car Cash Potential Index (CPI), this criteria covers 3 major intra-automobile interactions accept that includes: the braking requirement of acceptor automobile to prevent accidents and car cash, maximum braking power of acceptor automobile and elapsed time during the interaction.

The first accept can be identified by the DRAC criteria that its prediction and estimation are done by using Newton's physics equation for each time interval. The second parameter is the maximum possible braking or maximum available deceleration rate is a random component and due to the various categories of automobiles and different environmental conditions, it os expected that in various situation of braking which need a certain level of DRAC and it has a different behavior.

Reduction deceleration rate to prevent cash cars (DRAC)

The DRAC parameter can be computed for both types of interactions from backward and side.

In the third parameter, the overall time of intra-automobile interaction corresponds to a time which the accident conditions has been observed. Due to this fact, it is necessary to consider it in safety performance criteria. On this basis, car cash potential index (CPI) is defined.

2. Methodology

In this research is based on constructing a simulator model of a signalized saure as a case study by using one of the traffic simulator softwares avaibale in the market. On this basis, a analyzing-behavioral model which is the basis of micro simulator formation for modelling the signalized squares and evaulating the saftey performance by using the outputs of these models and secondary analysis, are suggested in the following and the process is shown as a flow chart in figure 1.

In general, the safety performance of a traffic system is considered with this assumption that it is a function of geometric characteristic of the path, traffic conditions, environmental conditions and their interactions to users' behavior, and it can be evaluated.

Providing an optional definition of the intra-automobile interaction is a necessary tool to measure the safety performance of signalized squares. And the importance of this issue is because these events determine the types of at risk automobiles. Intra-automobile interactions are described based on the collision situations between two automobile over time. In general, traffic collisions are recorded to a non-continued mode only in occurrence sudden movements such as sudden velocity reduction (sudden braking). The car which started the movement cause to interaction or collision occurrence and it will be identified as the (driver) automobile.

In this type of interactions, automobile is the ahead vehicles and in order to velocity adjusting in the time of facing the stop sign, yellow light or the rotating movements in the square filed is the changing variable. These type of interactions occur with some of the reasons that we can mention to them as sudden change in automobile line and in this situation the acceptor automobile is moving faster than the agent automobile in the line (Backward interaction) [5].

Determining the micro-simulation framework of traffic flow in the safety performance modeling process is the most important phase of each transportation systems and the importance of this issue is double at the signalized squares due to the automobile behavioral complexity. And sue to this fact, the simulation algorithm is necessary to have high repeatability for various traffic scenarios and high accuracy for a wide range of traffic situations leading to traffic accidents. Only then, we can assure of the output results performance which provides the comparing possibilities of safety performance with the situation close to reality of these squares. To construct a simulation model for a signalized square, the first step is to identify the involved parameters in the system performance that are included in three main groups: 1-geometric design parameters, 2-system traffic characteristics, 3-the driver's behavioral type [6]. By reforming these variables and constructing an initial and coordinated platform with the studied environmental conditions, we need for calibration of deriver's behavior parameters of this system [3]. After assurance of input variables identity with the observed variables, we can run the simulated model and observe the input automobiles to system according to the source-destination decision matrix. And in the end, by using the output of simulated model includes the information of automobiles trajectory and time series of traffic data in the system for the all simulation time, we can run the analysis of safety performance and ultimately the model validation. In the end, by running the various traffic scenarios and performing the variance analysis, we can observed the main effect of each main variables on the safety performance criteria of system [7].

3. Main parameters of triple models in AIMSUM software

Table 1 shows the input parameters to AIMSUN model and the related components that the driver's performance behavior is effective in this program. Parameters which are addressed in signalized squares are presented in ad separate table, in the following. In this research by conducting the field data studies and taking local data in case study of driver's behavioral patterns during moving in this system, the main effective factors are checked in the frame of intra-automobile interactions [5]. And these parameters are analyzed and they are describing in the following which are considered in the calibration of simulated model and they are presented in table 1 and 2.

Table. 1. The main parameters of triple models in AIMSUN software

vehicles characteristics	network locating	Input Demand	Local parameters
-Vehicle type -length -width -maximum desired velocity -maximum deceleration -normal deceleration	-maps or the aerial photographs of the studied region -the geometric characteristic of the system	-traffic flow in each sections -source-destination matrix -frequency in public transportation	-velocity limitations in sections -velocity limitation in line-section Velocity limitations in rotation movements

Table 2. Parameters and descriptions of simulation

Description	Parameter
Maximum visibility distance of drivers when entering another section of square, considering that a car distance in a sub-path (approach with lower input demand) is greater from collision area, so he actually decides to stop in front of this area. Note that amounts of less than a meter in model result in vehicle stop forever, this is because, according to settings for driver behavior in model, this car is not close enough to collision area.	Visibility
The time interval between rear part of car in main path (circular) and the front part of car in sub- path (input approach). For example, the proposed passed time from vehicle exit point with pass priority of collision area until the arrival of acceptor vehicle to this area.	The minimum pass distance
The minimum distance between the rear part of car in sub-path and front part of car in main Path. For example, the time required for operating car exit (violating) from collision are before arrival of car that has priority to pass this area.	Side crossing space
This amount is coefficient of normal optimal safe distance of a car in sub-path that is the minimum time interval required for entrance of vehicle to mainstream in order to prevent convergent collisions along conflict.	Safe distance factor
Selecting this option, sub-path cars consider the movement of adjacent line when entering the mainstream that actually speed of simulation comes down.	Check adjacent line

4. Description of the computational algorithm and safety performance criteria

Input information to the algorithm are obtained from the output file of AIMSUN simulator software contains of automobiles trajectories which are saved with .fzp. By entering this information, the program can conduct the related calculations of measuring the alternative criteria of safety performance related to the intra-automobiles interactions and it should specify that each of these intra-automobiles interactions have a essential characteristic to select a "collision position" or it is detected as a undisturbed passage [5].

After that an output file with a (.CSV) format is created that each character is separated with a "," and it has the capability to review and processing the software such as Excel and spss and it includes the key characteristic of collisions and alternative measures of safety performance. Fig. 1 indicates the general structure of this process.

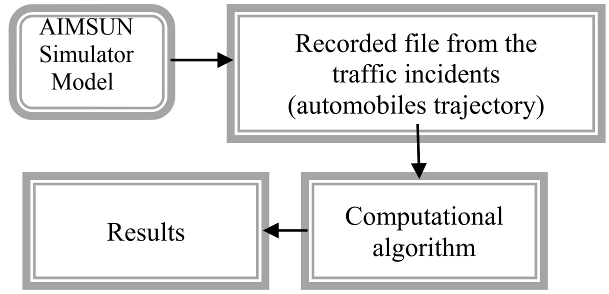

Fig. 1. General AIMSUN Simulation Model

By entering the data into a computational algorithm, we can calculate the values of CPI, DRAC, and TTC as 3 main criteria of safety performance of intra-automobile interactions in signalized squares and comparing these values with upper and lower limits. Default value for the domain of collisions due to the TTC criteria is the interval of 0 to 1.5 second. ,lower values than zero means the impossibility of collision due to the low velocity of racing automobile proportional to ahead automobile and values greater than 1.5 shows the undisturbed passage situations.

DRAC criteria for larger values are from 0 to 3.35 m/s² indicates the collision absence. If this criteria for taxi and personal cars are between 3.35 to 12.69 it indicates the collision situation and if this criteria is between 3.35 and 7.98, indicates the collision situation for BRT buses. If the DRAC amount for private car and taxi is more than 12.69 to 15, it means the accident occurs and it is unrealistic, because in reality, such a situation has not been seen.

This situation relates to unusual situation in model so the DRAC amounts which are placed in this range are neglected and they are counted in the output of algorithm, alone. Similarly, if the DRAC amount for bus and BRT is more than 7.98 to 15, it means the accident occurrence and it is excluded from the analysis. According to previous studies and investigations in this study, the DRAC values equal and greater than 15 are practically unacceptable and they are eliminated in algorithm calculation after identification and they are not included in results. This condition occurs when 2 automobiles occupy one place in a same time it means that they have a same x which is impossible.

The CPI value for each automobile is related to DRAC values for that algorithm in the previous step, so after calculating the key, DRAC values for each of automobiles in the travel time in system, algorithm compare the DRAC for all types of automobiles with identified MADR variables [6].

According to the provided description in the previous section, MADR value for taxis and private cars equal to 8.45 m/s2 and for conventional bus and BRT is equals to 5.10 m/s2. Therefore if the calculated DRAC at each time interval for each automobile in the previous step from MADR become greater, the probability of CPI equation equals to 1 and otherwise it will be equals to 0.

Finally, by comparing the calculated DRAC for each automobile with MADR at the total travel time of automobile in system, the CPI value is calculated for it.

There are some parameters that they are important also as follows [5]:

- Maximum reduction deceleration
- Acceptance of velocity restrictions
- The minimum distance between two automobiles
- Maximum waiting time for passage Yield sign
- Control steering acceptance
- Coefficient to reduction deceleration of automobile
- Minimum time interval

- The percentage of remaining automobiles at the racing line after line changing
- Percentage of overtaking automobiles from slow line
- Percentage of imprudent overtaking
- authorized actions defined in the system
- Velocity limitations
- Identifiers
- control signs and lights
- Public transportation lines
- Public transportation stations
- Junctions type (signalized -without light)
-Visibility distance at junctions
- Time interval for the next movement place
- Path slope
- Maximum range of Yield sign passage
- Domain time of cars response change

5. Case study

Given the geometry of 22 Bahman Square, the number of movement lines is different for this path at different times and unusual behavior of drivers of vehicles can be seen.
In this study, traffic volumes data entering 22 Bahman Square include: The input and output of each approach and combinations of circular motion around the central island of square using 3 statistical data. Transition regions, Transition areas.
Extensive reviews and analyses using field studies and video recordings show that speed reduction and acceleration decline of output areas particularly in northern and western sides of 22 Bahman Square is visible. In fact, vehicles when pass interference areas on circular route, have much higher instantaneous velocity than input and output of square because of more maneuvering space and greater movement width with the capacity of 6 cars together in some sections of path. But because of taxis accumulation in square output and also, because of steep angle of circular direction compared to output approach and narrowing of path width at exit approaches, a temporal bottleneck occurs which reduces the speed of cars due to braking process and interrupted accelerations at this area.

Fig.2. Point and areas in simulation

Velocity profile of selected areas 1 and 2 in Figure 2 is estimated at intervals of 4.5 to 6.5 m. accordingly, the analysis results show that speed reduction profiles and reduced acceleration in areas 1 and 2 of 22 Bahman Square show different trends. For example, in area 1 with respect to initial acceleration of vehicles to start from stop mode, there is no effective reduction in speed. In Figure 3 the relation between speed and distance to point A is described. At the beginning of area at a distance of 50 m to point A on northern approach, mean speed was 42 km/ h, while arriving output of northern approach, speed is varied from 18 to 32 km/ h, most of the day due to traffic congestion caused by taxi stop at 2 adjacent line paths. Percentage of vehicles slowing speed is over 80%.comared to total passing vehicles. Reducing acceleration rate of area 1 corresponds to reduced speed of this area and is averagely of 0.81m/s2 which increases substantially to 2.1m/s2 in are 2.

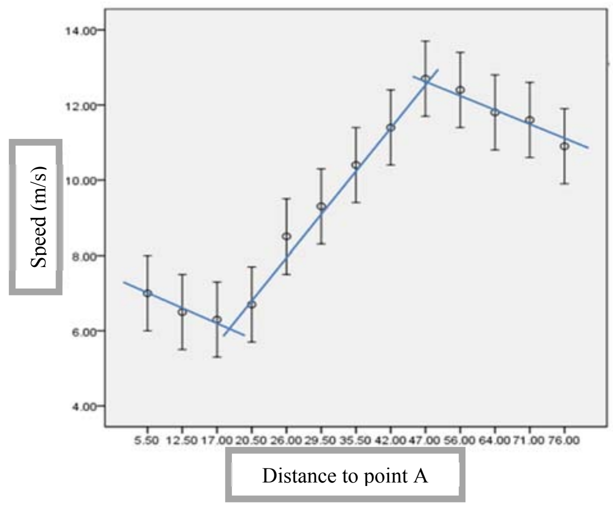

Fig. 3. Velocity Profile

6. Validation of 22 Bahman Square simulation model

Logic of this study is to validate the simulation model of 22 Bahman Square by AIMSUN program, based on comparing output data of this program and recorded data from field observations and analyzing recorded videos from site.
The aim model validation is to explore the possibility of expanding output results of calibrated model for immune function measures in other comparable situations of reality. Typically for this purpose, video recordings in 2 periods of 15 minutes are analyzed and evaluated, once for calibration operation and then for validating model that the same approach was chosen in this study.
The results show that AIMSUN model has ability to simulate interaction between cars in signalized square so that the maximum deceleration is in area 2 as observed in Figure 2 and according to results obtained by computational algorithm for measures of immune function using the simulation model output; the most deceleration has been done in this area.
Effect of flow rate volume on density and speed and number of Taxis enter to square from west approach according to Origination - matrix was evaluated according to source – destination matrix for 22 Bahman Square is negligible and is not considered in this analysis. Due to the fact that the performance of signalized square is more close to signalized intersection than a common Square, field observations also suggest that major movements are in north-south, east - south and south - north direction, specifically, in the present case that traffic restrictions are on north- south side of Square.

However, the percentage of vehicles that travel south to west and west to north paths are effective on safety performance of system. These two groups of movements are left turn movements and given the nature of their movement and combination of this movement with movements influence directly on decisions of drivers. Table 3 shows the classification between traffic parameters of each level.

Table 3. Classification of different traffic parameters associated with each level

Change level				Traffic parameter
[redacted]	[redacted]	2	1	Movement area
[redacted]	4000	2000	1000	The total inflow volume (Vehicles per hour)
Eastern approach		**Southern approach**		Percent of taxis in traffic flow
40	**20**	**50**	**25**	
[redacted]	[redacted]	Southern approach		Percent of turn left movements

Multivariate ANOVA analyses with interaction between variables was performed for 24 scenarios and are summarized in the table II on two traffic areas for DRAC measure and values related to their significance level.
According to above table, results show that volume factors of taxis and area have a significant impact on DRAC measure at 5% significance level. This indicates that these factors play an important role in explaining more risky behaviors in traffic flow.

7. Conclusion

The important results obtained in this study can be summarized as follows:
1. Traffic Micro-flow simulation approach has the ability to describe the specific causal and specified relationships that can effect on immune function of signalized squares and covers the limitations of traditional statistical methods in collecting and identifying effective factors.
2. The combined behavior of vehicle drivers when passing through the route around central island and paying attention to the geometry and phasing of lights cause that each section of square and, in particular, the output part of approaches have different traffic functions. According to the numerous speed profiles and reducing acceleration of this area, study and assessment of performance safety of this system requires separation of motion sections and of course, with a degree of overlap so that studying the vehicles path be possible in these sections. In other words, separating areas of slowdown in circular path around a central island of square, somewhat more uniform behavior of vehicles can be seen that not only allows a more precise calculation of safety performance measure, but also, makes possible calibration and validation of model based on video recordings. These areas are selected based on distance between vehicles and output paths, radius of movement paths and rotation angles around the central island of Square. In this regard, the results are as follows.
2.1 Regardless of effective factors and those that change trajectory of vehicles, generally vehicles entering the square, no matter in the beginning of motion from stop lights or moving in green lights, they will have speeds between 35 and 42 km/ h with their corresponding phase to the circular motion around central island of square with an initial acceleration that will accompanied by a loss in circular motion and again when leaving the square, because of narrow width of path and slow cars in the right line, they will face a cross interference in opposite flow and also, will experience even speed of 18 km/ h.
2.2 Selecting the movement lines by cars is largely uniform when begin to enter the path regardless of geometric and traffic factors and uniform motion pattern is visible among different vehicles, but when they approach the middle of the path and after circular motion, cars distance from each other for faster unloading square and are distributed in path. Two parameters of reducing acceleration rate and selecting movement line are main factors that determine the traffic performance and safety of signalized Squares.
2.3 generally, low rates of entry into square, square performance with minimal interference movement show safe passage of vehicles from output paths, but with the increase of traffic flow to model and more cars entering in different directions to the square, average speeds of movement on square is reduced, however, due to the presence of more cars, possible interactions of collision will increase and this is specifically defined in area 2 and can be seen in present study and collisions will be less due to difference of speeds and movement at lower distances. with excessive traffic and approaching system to saturation conditions, speed of movement will be accompanied by a sharp drop and similarly velocity difference will be negligible, however, due to the lower density of vehicles and less distance of vehicles from each other, any risk behavior of operating vehicles can be accompanied with adverse reactions of car and can provide surface collisions. Hence, in this case, with respect to the free stream, percent of more likely collisions will be more but far less than the average volume that is 2,000 vehicles per hour.
2.4 With regard to defined movement restrictions in this study, only 2 groups of left turn movements of vehicles entering from south and west approaches can be seen. Specifically, the effect of these movements on following cars that are passing from area 1 in southern path has been defined, so that less percentages are due to temporal loss and direction change of operating cars when doing circular movement, following vehicles need braking and change of movement towards right and according to small number of these movements and open flow at downstream, following cars are less acknowledged on this type of stimulus and move with more speed and sometimes non-compliance with safe distance to the vehicles ahead in path. Generally, reducing rate of acceleration for following cars in area 1 has increased substantially in this case compared to when there is no left turn movement and undisturbed flow is dominant and result is increased likelihood of risky collisions. While increasing left turn movements and flow out of area 1, speed drop of following vehicles occurs and in this case, vehicles face a dominant mainstream and similarly will be restricted choosing movement speeds and desired motion lines. Therefore, the difference in speed between following vehicles and vehicles ahead is dropped and effectively reducing rate of acceleration is very small that is due to temporal acceleration and braking when passing area 1 and entering area 2 in circular direction.
2.5 Results analysis show that percentage of taxis entering square from sought and east approaches effect on interactions between vehicles entering from sought. In fact, increased percentage of taxis in system, refers to more irregular movements and create bottlenecks at north of square that will result in speed loss of sought path movements in circular path and generally, more risky collisions are reduced. When the percentage of taxis is less in system, speed difference will increase due to reduced likelihood of risky maneuvers by drivers of these cars who are going to stop at north edge of square and according to less stop of taxis at area 2, there will be more possibility of collisions because of failure to observe proper safe distance and following vehicle speed. However, this issue effects less on taxis entering from south and the

reason for risky interactions is the presence of taxis entering from east in front of following cars from south paths.

3. in this study, according to studies in simile experiences of other intersections and analyses on capability of safety performance measures in interpreting risky positions, 3 measures of DRAC ، TTC and CPI have been selected as proper measures of evaluating signalized squares performance among present alternative measures of safety performance that main measure is DRAC and two other measures are used only for case study and analysis. Results showed that time measure of TTC face some deficiencies in interpreting potential positions of collision in traffic especially in circular path around Central Island of signalized squares that leads to the fact that this measure cannot be used for analysis and evaluation of traffic system performance. In fact, according to selection of signalized squares as traffic system and high percentage of rear collisions of these squares compared to side collisions, the important and effective variable on safety performance criteria is the rate of reducing rate that effect directly on DRAC and CPI measures.

The proportion of CPI measure is greatly close to DRAC but despite a relative dominance of CPI measure compared to DRAC, its very small amount does not offer proper understanding of severity of collisions because of considering requirements of braking by following vehicle to prevent accident (Variable MADR) of each vehicle and vehicles time in interaction situations. Therefore, DRAC criteria have been implemented in different scenarios according to traffic parameters changes and confirm increase in intensity and number of possible collisions at area 2. In other words, the difference in speed between fewer distances expresses larger amounts of DRAC.

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