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A new microsimulation model for the evaluation of traffic safety performances

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Abstract

Some papers have been recently presented (Cunto and Saccomanno 2007, Cunto and Saccomanno 2008, Saccomanno et al. 2008) on the potential of traffic microsimulation for the analysis of road safety. In particular, studies have confirmed that the reproduction by simulation of user behaviour under different flow and geometry conditions, can identify a potential incident hazard and allow to take appropriate countermeasures at specific points of the road network.

The objective of this paper is to assess the validity of this approach; for this reason a microsimulation model and an automatic video detection system have been developed. The microscopic model allows the estimation of road safety performance through a series of indicators (Deceleration Rate to Avoid Crash, Time to Collision, Proportion of Stopping Distance), representing interactions in real time, between different pairs of vehicles belonging to the traffic stream. When these indicators take a certain critical value, a possible accident scenario is identified.

The microscopic simulation model is used combined with a new video image traffic detection algorithm to calculate vehicle trajectories. Microscopic traffic flow parameters obtained by video detection are used to calibrate the microsimulation model, and the safety performance indicators obtained by the real vehicles trajectories can be compared with simulated scenarios where safety performance indicators are obtained on the simulated trajectories.

Results indicate that the methodology can be useful in the estimation of safety performance indicators and in evaluating traffic control measures.

Keywords: Traffic simulation, Road safety, Video traffic detection.

Introduction

In the last few years the growing need for mobility by users has coincided with a greater increase of congestion levels on transportation infrastructures and a consequent repercussion on safety aspects. For this reason researchers and technicians have, as main objective, the study of safety performance on road network identifying and applying all kinds of countermeasures useful to decrease accident risks. Due to the limited budget and resources available to government agencies it is necessary, once risk scenarios are

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identified, to maximize the economic performance of the countermeasures without reducing their benefits. This aspect, however, involves an adequate verification of the impact of planned interventions before their implementation on the site under study. One of the most common methodologies to estimate safety makes use of inferential statistics applied to crashes databases therefore being considered a reactive approach to the problem. Although this method seems to intuitively link the causes to effects, a good knowledge of the dynamics of the events preceding the crash may provide a more useful support to the implementation of appropriate countermeasures. Moreover, the problems of consistency and availability of crash data as well as the methodological challenges posed by the extremely random nature and the uniqueness of accidents have led to the development of complementary approaches to improve road safety assessment, such as the observation of traffic conflicts and the use of microscopic traffic simulation. The potential of microscopic simulation in traffic safety and traffic conflicts analysis was initially investigated by Darzentas et al. (1980) and has gained a growing interest due to recent development in human behavior modeling and real time vehicle data acquisition (Cunto and Saccomanno 2007, Cunto and Saccomanno 2008, Saccomanno et al. 2008, Yang et al. 2010, Cheol and Taejin 2010). However, a proper use of microsimulation is subject to a correct determination of input parameters based on observational data that produce estimates of safety performance that can be verified from real world observations.

The objective of this paper is to assess the validity of a microscopic framework to identify potentially unsafe vehicle interactions for vehicle movements based on car-following behavior protocol (potential rear-end crashes), providing a link between simulated safety performance indicators and observed high risk vehicular interactions. The microscopic model presented (TRITONE) provides a framework for simulation modules that can consider both freeways and arterials; different traffic scenarios can be reproduced and different simulation models can be applied. The model was developed to overcome limitations of many commercial traffic microsimulation packages that are not open sourced and are unable to modify simulation procedures and evaluate traffic safety performance through a series of indicators (Crash Potential Index, Deceleration Rate to Avoid Crash, Available Maximum Deceleration Rate, Time to Collision, etc.), representing interactions in real time, between different pairs of vehicles belonging to the traffic stream. The simulation model TRITONE intends also to reproduce Intelligent Transportation Systems such as ATMS and ATIS and to give a coupled modeling of traffic and safety performance. In TRITONE the traffic components are microscopic and attributes of traffic flow can be represented as resulting from individual vehicles movements. It is also possible to consider macroscopic traffic flow relationships by using car following models based on macroscopic link characteristics such as free speed and capacity. The combined use of individual vehicles and macroscopic flow theory has been inspired by the microsimulation model INTEGRATION (Van Aerde et al. 1996) that in the past has been considered mesoscopic by some researchers.

The most common traffic models today are based on the representation of driver behavior regarding car following, gap acceptance and lane choice. There are many examples of this type of micro-simulation models such as CORSIM (http://www.fhwa-tsis.com/corsim_page.htm), INTEGRATION (Van Aerde 1999), AIMSUN2 (Barceló et al. 1994), VISSIM (PTV 2005), PARAMICS (http://www.quadstone.com), DRACULA (http://www.its.leeds.ac.uk/software/dracula/) and MITSIM (Yang 1997) that is an academic research model used in several studies in Boston, Stockholm and elsewhere. The success of micro-simulation models is related to the analysis of relatively small size networks and consequently their application for medium-to-large networks involves an high computation time and effort required for a proper model calibration. The aim of handling larger networks with relatively small computational times has led to the development of so-called "mesoscopic" approaches to traffic simulation, which, however, are less precise in the representation of traffic behavior. One of the earliest examples of this approach is CONTRAM (Leonard et. al. 1989) which is a commercially available package that has been used in England and elsewhere in Europe. Recently, the research activity focused on the development of mesoscopic simulation models for off-line dynamic traffic assignment, as witnessed by the Dynamic Traffic Assignment Project edited by United States Federal Highway Administration (http://www.dynamictrafficassignment.org). For this purpose DYNASMART (Mahmassani et al. 2001) and DYNAMIT (Ben-Akiva et al. 1998) are two significant developments. These mesoscopic models provide a path choice mechanism and a network loading method based on simplified representations of traffic dynamics (Florian et al. 2005). While CONTRAM, based on static traffic assignment models, represents traffic with continuous flow, DYNASMART and DYNAMIT move individual vehicles. In literature there is another approach to the network loading algorithm that is based on cellular automata theory (Nagel and Schreckenberg 1992) and has been implemented in the TRANSIMS software (http://transims.tsasa.lanl.gov), developed by the Los Alamos National Laboratories in the USA. There are other dynamic traffic assignment models based on macroscopic traffic flow theory developed during the 1950's (Lighthill and Whitham 1955, Richards 1956). Subsequent developments of this approach led to the definition of METACOR (Diakakis and Papageorgiou 1996) and METANET (Messmer et al. 2000a), which are based on a iterative dynamic traffic assignment method (Messmer et al. 2000b).

The paper is organized as follows. The following section describes the safety performance indicators functional form and discusses the basic concepts that the safety performance indicators are based on. Next is a section in which the microsimulation model (TRITONE) features are described and the subsequent section is focused on the TRITONE calibration and application on a case study. The paper concludes with some comments and practical recommendations.

Safety performance indicators

Safety performance indicators represent traffic interactions between vehicles in a traffic stream and highlight potentially unsafe traffic conditions. According to the Federal Highway Administration (FHWA 2003), when properly formulated safety performance measures can provide a useful platform from which to identify high risk situations in the traffic stream and guide cost-effective intervention strategies. Safety performance indicators provide a causal or mechanistic basis for explaining complex time-dependent vehicle interactions that can compromise safety (Hayward 1971; Minderhoud and Bovy 2001; Huguenin et al. 2005).

Safety Performance is influenced by a number of traffic and geometric factors, such as driver features and conditions (experience, stress, tiredness, etc.), road characteristics (type of road, road surface, geometric features, etc.), traffic conditions (volume, speed, density, etc.), vehicle attributes (maneuverability, braking capability, stability, etc.), and environment (weather conditions, light conditions, etc.) (Elvik and Vaa 2004; Ogden 1996; Evans 1991).

Vehicle interactions in the traffic stream have been represented by Hyden (1987) in terms of a “safety performance pyramid” (Fig. 1). Hyden’s pyramid represents all likely interactions, ranging from more frequent undisturbed events at the base of the pyramid to less frequent higher risk events nearer the peak (i.e. traffic conflicts and crashes). A comprehensive assessment of safety at a given location must reflect the full spectrum of these vehicle interactions, since in some “unlucky” cases crashes can occur near the base of the pyramid where conditions are “potentially” safer. Conventional crash prediction models focus on reported crashes, and hence fail to consider unsafe interactions but have not “yet” resulted in reportable crashes.

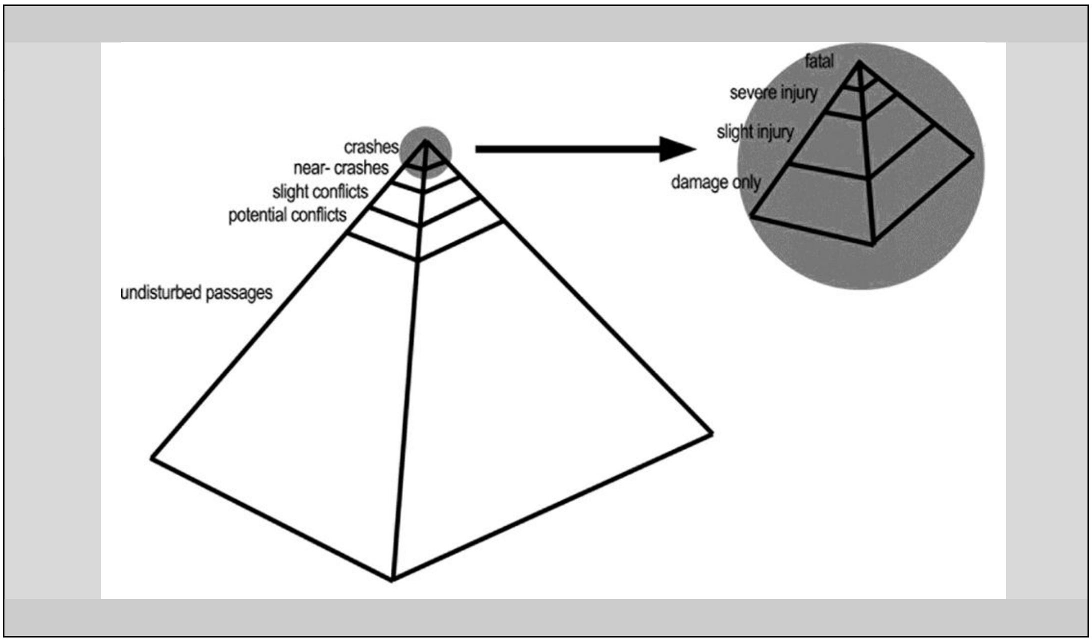


Figure (1): Hyden safety performance pyramid

In this paper, safety performance is expressed in terms of three indicators: Deceleration Rate to Avoid the Crash (DRAC), Time to Collision (TTC) and Proportion of Stopping Distance (PSD).

A recent PhD dissertation by Archer (2005) has explicitly recognized the relevance of DRAC as a measure of safety performance. DRAC explicitly considers the role of speed differentials and decelerations in traffic flow.

DRAC was defined by Almquist et al. (1991) in terms of the speed differential between Following Vehicle (FV) and Lead Vehicle (LV) divided by their closing time. The LV is responsible for the initial action (braking for a traffic light/stop sign, changing lanes and/or accepting a gap), while the FV responds to this action by braking. For rear-end interactions, the FV deceleration expression is:

$$DRAC_{FV,t+1}^{REAR} = \frac{(V_{FV,t} - V_{LV,t})^2}{2 \cdot [(X_{LV,t} - X_{FV,t}) - L_{LV,t}]} \qquad (1)$$

where,
t = time interval (s)
X = position of the vehicles (m)
L = vehicle length (m)
V = speed (m/s)

DRAC is updated every 0.1 second time interval based on driver reaction from the previous interval based on an assumed maximum comfortable deceleration rate. American Association of State Highway and Transportation Officials (AASHTO 2004) recommends 3.4 m/s^2 as a maximum comfortable deceleration rate for most drivers. Archer (2005) suggests that a given vehicle is in traffic conflict if its DRAC exceeds a threshold braking value of 3.35 m/s^2, and this is the value we have adopted as a threshold in this paper.

TTC can be defined as expected time for two vehicles to reach a common position on the road assuming their speed and trajectory remain the same and can be calculated using the following expression:

$$TTC_{i,t} = \frac{(X_{LV,t} - X_{FV,t}) - L_{LV,t}}{(V_{FV,t} - V_{LV,t})} \qquad (2)$$

where,
t = time interval (s)
X = position of the vehicles (m)
L = vehicle length (m)
V = speed (m/s)

Time to collision was defined by Hayward (1971) to reflect the time separating a given FV from its corresponding LV, where their differential speeds are such that both vehicles are closing in on each other. The basic assumption is that the FV maintains its speed despite it's being on a collision path. When TTC is lower than a threshold value of 1.5 seconds (minimum perception/reaction time) suggested by Van der Horst (1991), the two vehicles are assumed to be in conflict or in an "unavoidable" collision path.

Proportion of stopping distance as defined by Allen et al. (1978), is the ratio between the remaining distance to the potential point of collision and the minimum acceptable stopping distance. For the FV this measure can be expressed as:

$$PSD = \frac{RD}{MSD} \qquad (3)$$

where,
RD = remaining distance to the potential point of collision (m)
MSD = minimum acceptable stopping distance (m)

$$MSD = \frac{V^2}{2d} \tag{4}$$

where,
V = approaching velocity (m/s)
d = maximum acceptable deceleration rate (m/s^2)

Microscopic simulation model

General description of TRITONE features

TRITONE software has a graphical interface with a fully graphical input data management. The interface is projected for an easy accessibility to all commands and for easy use and choice of all operations.

The operations that are fundamental in the microsimulators are three:

- the data entry module, in which the user can define the geometry of the network, its characteristics and the circulating flow,
- the simulation of vehicles movements, which attempts to reproduce as realistically as possible the man-machine-road system,
- the results reporting module that allows the user to assess the outcome of the simulations.

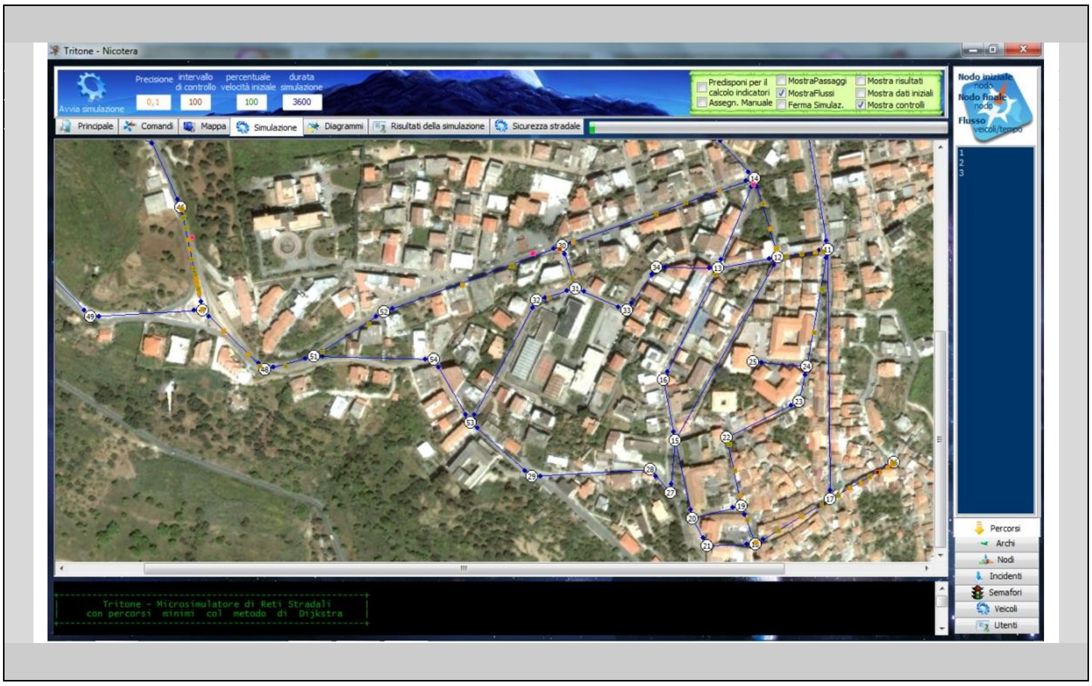
Data entry module

Some of the data necessary in TRITONE to run a simulation can be introduced directly on an orthophoto or a map for an easier representation of the network during the input procedure. Nodes can be placed directly on the screen superimposed on the map, the links that represent uniform road sections can be entered easily by clicking on nodes on the screen and associating properties such as initial node (for direction), length, free flow speed, capacity , number of lanes and longitudinal slope. Path flow values can be introduced also on a graphical interface. Other optional input can have an important role in the simulation of road networks like the temporary reduction in capacity of a road due to construction or accidents, intersections input data and traffic lights data.

Another essential input is the distribution of driver attitude and the distribution of vehicles characteristics.

To obtain a more accurate simulation some differences in driving attitudes that are present in the real world are considered. In fact some drivers tend to travel at the full speed allowed on the road on which they are traveling, always looking for an overtake possibility, with a resulting higher average speed performance, while other can drive more safely, avoiding overtakings and keeping speeds always below the limit.

In the simulation model each driver is categorized into a driving style type with a desired speed function of the free flow speed. In the simulation each driver will tend to his desired speed consistently with the link free flow speed and its driving style category. Users are generated to on each path following a normal distribution for the driving style resulting in a normal distribution for the desired speed on each single link. The distribution of speeds will be centered on the free flow speed, the result is that on each link the free flow speed is the average value for the distribution of desired speeds among drivers.


Tritone - Nicotera

Precisione 0,1
intervallo di controllo 100
percentuale velocità iniziale 100
durata simulazione 3600

☐ Predisponi per il calcolo indicatori
☐ Assegn. Manuale
☐ MostraPassaggi
☑ MostraFlussi
☐ Ferma Simulaz.
☐ Mostra risultati
☐ Mostra dati iniziali
☑ Mostra controlli

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+-----------------------------------------------------+
|        Tritone - Microsimulatore di Reti Stradali   |
|     con percorsi  minimi  col  metodo  di  Dijkstra |
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Figure (2): Graphical user interface of TRITONE.

Simulation of traffic movements

In TRITONE, drivers following their pre-determined routes interact with other vehicles on the road. The simulation maintains a linked list of vehicles in each lane and their space-time trajectories are determined according car following and lane-changing models.

Car-Following Model

The car-following model regulates driver's behavior with respect to the preceding vehicle in the same lane.

A Free-moving condition occurs when a vehicle is not constrained by another vehicle or if the headway from its preceding vehicle on the same lane is more than a pre-defined threshold h^f. In this condition the vehicle will accelerate or decelerate freely in order to maintain its desired speed.

In the car-following regime the space headway becomes shorter than h^f but longer than a lower threshold h^c; the vehicle will take a controlled speed which is derived from the relative speed and distance of the preceding vehicle according three different car-following models that can be chosen by the user:

- the Gazis-Herman-Rothery (GHR) (Chandler et al. 1958) model that is sometimes referred to as the General Motor car-following model;
- the model developed by Gipps (Gipps 1981);
- an unsymmetrical GHR model (Yang and Koutsopoulos 1996).

Lane-Changing Model

The lane-changing model is divided into three steps: (1) obtain the lane-changing desires and define the type of changing, (2) select the target lane, and (3) change lane if gaps are acceptable.

There are two type of lane change : mandatory and discretionary. A mandatory lane change occurs when the lane-changing has to be carried out by a certain position on the current link. Whether a discretionary lane-change can be carried out depends on the actual traffic conditions. An example is a vehicle that would only change lane to gain speed if the speed offered by the adjacent lane is higher by a threshold.

When a vehicle wishes to change lane, it looks for a target lane. Once it has chosen a target lane, it evaluates the “lead” and “lag” gaps in its target lane and makes the lane-changing movement immediately if both gaps are acceptable.

Results reporting

In output TRITONE provides individual vehicles’ locations and speeds every 0.1 seconds, and provides point-based or loop-based detector measures on headway distribution, flow, occupancy and speed. TRITONE can also provide some measures of safety performance, such as Deceleration Rate to Avoid a Crash, Time to Collision, Crash Potential Index, Time Integrated Time to Collision, Post Encroachment Time, Proportion of Stopping Distance, etc.

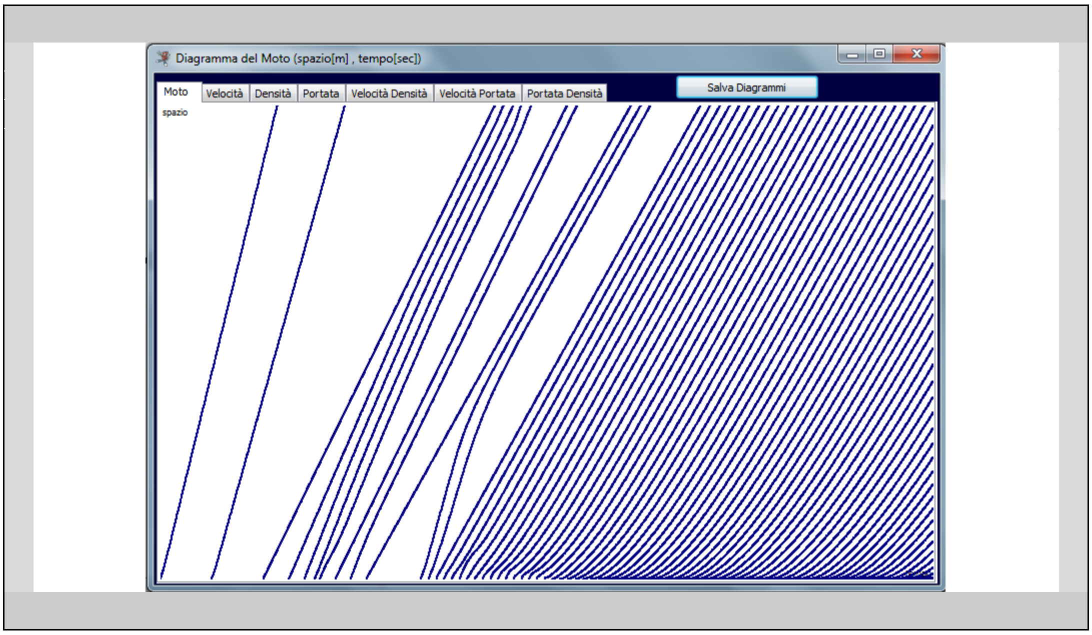


Figure (3): Space-time diagram for a specific link.

Case study A: safety performances evaluation on two-lane undivided rural highway

In order to illustrate the potential of the microscopic simulation model for reproducing real world phenomena and evaluating safety performance, a test was carried out. The road segment selected for these tests is a two-lane undivided rural highway located in Cosenza (Italy). The section analyzed consists of a straight stretch of 160 meters (Fig. 4).

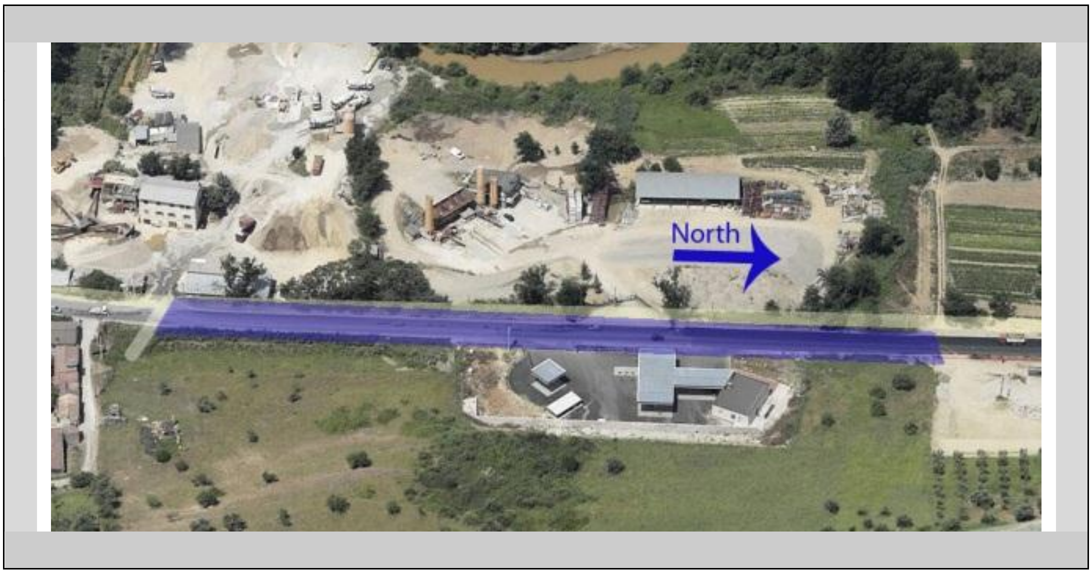


Figure (4): Observed/simulated sub-network.

The experimental field was monitored during two typical weekday between 9:30 am and 10:30 am, a period coincident with off-peak traffic conditions at this location. During the test, coinciding with the experimental survey, the observed traffic flow was 320 vph in north direction and 328 vph in south direction.

The individual vehicle trajectories were recorded by an High Definition digital camera and processed by a video image processing algorithm. The algorithm adopts a background subtraction-based approach for vehicle detection in 0.1 second increments. Since this approach is sensitive to background changes (or noise), a median filter technique has been introduced. Individual vehicles are detected and tracked using a region-based approach, whereby a connected zone (or blob) is assigned to each image, which is then tracked over time using a cross-correlation measure. In case of overlapping, where the designated blob may correspond to several vehicles, a real time sub-routine is accessed that manually discriminates each constituent vehicle’s specific position within the blob. Output from the algorithm application is expressed in terms of several trajectory descriptors over time, such as position and speed. Due to the high resolution images used during the video acquirement stage and, consequently, the large computational resources required by the video image processing algorithm, a video sample of 15 minutes was examined to obtain the traffic parameters in the observed field from the test.

Position and speed profiles obtained by processing the video images are assumed to provide “true” benchmark values for assessing the accuracy of the TRITONE microscopic simulation model.

TRITONE, like all traffic microsimulation models, generates different outputs in every run, therefore 10 runs were carried out to examine the results and to analyze the deviations around the average values. The thresholds adopted for the transition from the free-moving condition to the car-following regime and from the car-following regime to the close-following condition were, respectively, h^f=5 sec and h^c=1 sec.

The car-following model used for the simulations was the GHR model, in which the parameters assumed the following values:
$\alpha = 12.192$;

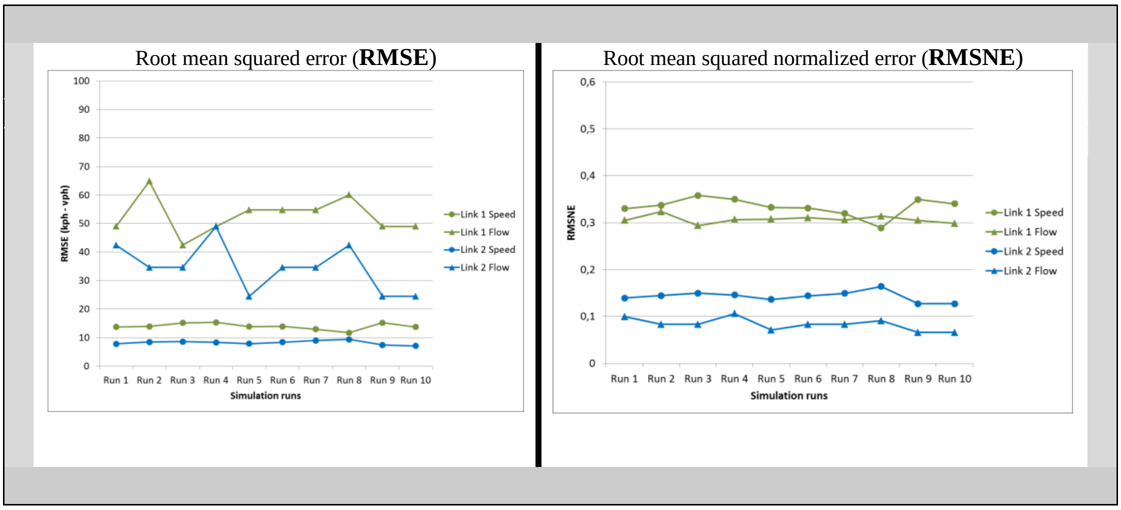
$\beta = 0$;
$\gamma = 1$.

In order to evaluate the differences between the simulation outputs and the observed measurements, two measures of goodness-of-fit were calculated: root mean square error or *RMSE* (Toledo and Koutsopoulos 2004, Dowling et al. 2004) and root mean square normalized error or *RMSNE* (Hourdakis et al. 2003, Toledo et al. 2003, Toledo and Koutsopoulos 2004, Ma and Abdulhai 2002). *RMSE* and *RMSNE*, that here were applied to the average travel speeds and flows, depend on the squared difference, and hence are more appropriate than the other measures for analyzing the errors in the context of stochastic traffic modelling. Observed and simulated speeds and flows were compared every 60 seconds; therefore, in order to evaluate *RMSE* and *RMSNE*, 15 time intervals were used. The results relating to the southbound link (link 1) and the northbound link (link 2) are reported in Figures (5).

$$\text{RMSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - y_i)^2} \qquad (5)$$

$$\text{RMSNE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(\frac{x_i - y_i}{y_i}\right)^2} \qquad (6)$$

where:
x_i = simulated measure
y_i = observed measure
N = number of evaluation time intervals



Root mean squared error (**RMSE**)

Root mean squared normalized error (**RMSNE**)

Figure (5): Comparison between simulation outputs and observed measurements of speed and flow.

By analysing the outputs of the simulations and comparing them to the observed speeds and flows, link by link, it is evident that the average RMSE in travel speed estimation is 13.98 kph, in link 1, and 8.27 kph, in link 2, while the average flow RMSE is 53 vph and 35 vph, respectively for link 1 and link 2. The average RMSNE of the travel speed is 0.33 for the link 1 and 0.14 for the link 2; the average flow RMSNE is 0.31 (link 1) and 0.08 (link 2).

On the basis of the previous results it could be assumed that simulation outputs were used to analyze vehicles interactions and hence to estimate the safety performance indicators.

The analysis of safety performance, expressed in terms of DRAC, TTC and PSD, was carried out for the vehicle paths both in link 1 and in link 2 for all the simulation runs, as showed in Table (1). In the table, for each link, the number of vehicles traversing the link, the average Time to Collision, the average DRAC, the average PSD, the average exposure time to risk according to PSD measure and the percentage of vehicles on collision risk according to PSD measure are reported.

Table (1): Safety performance indicators obtained from 10 simulation runs.

	Link	# veh.	Aver. TTC (sec)	Aver. DRAC (m/sec2)	Aver. PSD	Aver. exp. time to risk based on PSD (sec)	% veh. on collision risk based on PSD
Run 1	**1**	82	32.94	0.06	2.42	0.00	0.00
	2	80	24.67	0.07	1.90	0.00	0.00
Run 2	**1**	82	63.72	0.04	2.90	0.00	0.00
	2	80	33.07	0.08	2.68	0.30	1.25
Run 3	**1**	82	45.77	0.05	2.82	0.00	0.00
	2	80	41.24	0.08	2.37	0.90	1.25
Run 4	**1**	82	38.55	0.04	2.70	0.00	0,00
	2	80	41.96	0.07	2.24	0.00	0.00
Run 5	**1**	82	31.69	0.06	2.70	0.00	0.00
	2	80	30.28	0.09	2.37	0.30	1.25
Run 6	**1**	82	37.95	0.04	3.00	0.00	0.00
	2	80	32.44	0.05	2.25	0.00	0.00
Run 7	**1**	82	47.43	0.04	3.00	0.00	0.00
	2	80	35.04	0.07	2.30	1.10	1.25
Run 8	**1**	82	39.41	0.05	2.74	0.00	0.00
	2	80	30.96	0.07	2.71	0.00	0.00
Run 9	**1**	82	54.92	0.04	2.90	0.00	0.00
	2	80	25.91	0.07	2.43	0.00	0.00
Run 10	**1**	82	41.80	0.04	2.90	0.00	0.00
	2	80	32.52	0.07	2.12	1.10	1.25
Average	**1**	82	*43.42*	*0.05*	*2.81*	*0.00*	*0.00*
	2	80	*32.81*	*0.07*	*2.34*	*0.37*	*0.63*

The average exposed time to risk and the percentage of vehicles on collision risk are null according to TTC and DRAC values, while the average exposed time to risk varies from a low of 0.00 sec to a high of 1.10 sec; the percentage of vehicles on collision risk varies from 0.00 % to 1.25 %.

This can be explained by the low volumes observed that produced not many vehicles interactions. Indeed, vehicles were predominantly in free-moving condition. Furthermore, when simulated vehicles were in car-following regime TTC and DRAC, that are less sensitive than PSD to higher risk scenarios, highlight no risk of conflict in the traffic stream.

The average values of TTC, DRAC and PSD are, respectively, 32.81 sec, 0.07 m/sec^2 and 2.34. These results are in line with expectations, since during the survey the observed traffic flows were small, and hence the safety performance indicators rarely exceed the thresholds.

Case study B: stop-controlled intersection vs roundabout, comparison of safety performances obtained by microsimulation

In order to analyze the safety impact resulting from the conversion of an intersection regulated by stop in a roundabout, two scenarios have been implemented in TRITONE: scenario (A), representing an intersection with four entries regulated by priority and stop signs, and scenario (B), representing a roundabout with the same number of entries, asymmetric, whose geometric characteristics are shown in figure (1).

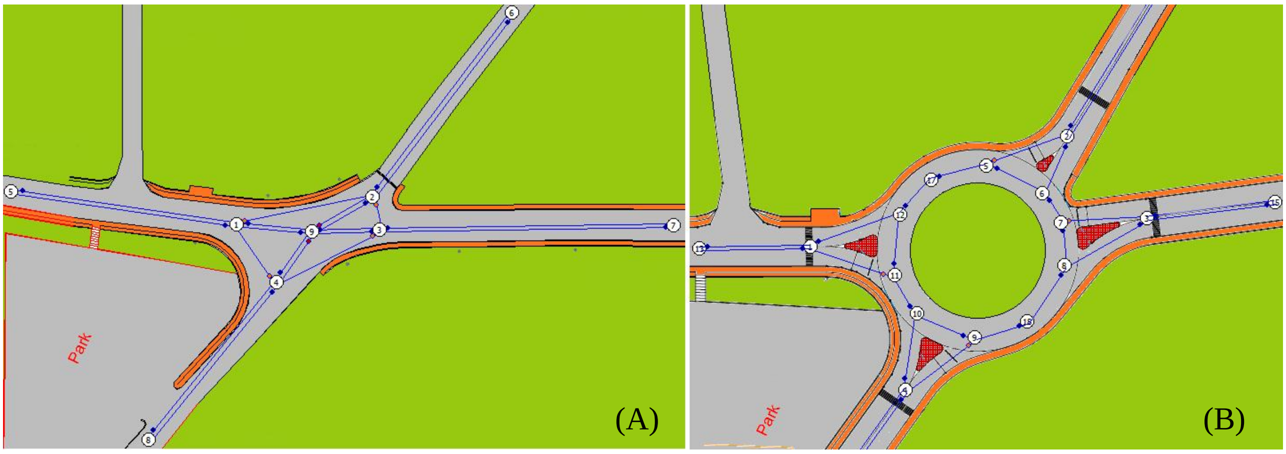


Figure (6): Stop controlled intersection (A) – Four-leg roundabout (B).

The geometry of the scenario (A) was reproduced on the micro-simulation software based on a topographic survey of an intersection actually exists in the university area of Rende (CS), affected by traffic volumes for the most part concentrated in the morning and afternoon peaks (respectively 8:30 to 9:30 am and 17:30 to 18:30). From a survey carried out between 9:30 am and 10:30 am in a typical week day, a total traffic volume amounting to 530 vehicles was observed.

On the basis of such information, it was possible to "draw" and simulate two scenarios with different geometry of the same node, assuming an alternative configuration to the real situation. The scenario (B) is in fact the result of a proposed commutation of an existing intersection into roundabout, in which the angles between the various entries are considered unchanged.

The two scenarios were simulated with TRITONE under the assumption that traffic volumes remain constant (were assigned traffic volumes coincide with those observed during the survey). This methodology was applied in order to analyze the effects on vehicle interactions and, therefore, safety arising from the introduction of a new traffic control element.

The results of ten simulations for each scenario are expressed in terms of two safety performance indicators: Time to Collision (sec) and Deceleration to Avoid Crash Rate (m/sec2). Table 1 shows the average values of the two indicators.

Table (2): Comparison of safety performance indicators obtained from 10 simulation runs

	Scenario	Aver. TTC (sec)	Aver. DRAC (m/sec2)
Run 1	**A**	1.65	1.12
	B	14.30	0.81
Run 2	**A**	0.75	0.30
	B	8.55	0.13
Run 3	**A**	1.24	1.05
	B	2.70	0.14
Run 4	**A**	3.28	0.58
	B	3.49	0.45
Run 5	**A**	5.44	0.69
	B	54.75	0.87
Run 6	**A**	1.46	0.28
	B	8.64	0.12
Run 7	**A**	4.99	0.33
	B	2.45	0.32
Run 8	**A**	10.32	0.46
	B	3.28	0.20
Run 9	**A**	2.98	0.84
	B	7.82	0.04
Run 10	**A**	2.83	0.62
	B	15.53	0.23
Average	**A**	*3.53*	*0.54*
	B	*7.46*	*0.33*

From the results shown in the previous table can be seen that, apart from two cases in terms of TTC and a case for DRAC, in all the simulations carried out the safety conditions are better in the scenario (B). Considering the same traffic flow conditions, vehicular interactions at the roundabout, seems to be less than those observed in the scenario (A): in ten simulations an average value of 3.53 sec for TTC is calculated for the intersection regulated by stop and 7.46 sec for the roundabout; on the contrary, at the intersection regulated by stop is calculated a mean value of DRAC (0.54 m/sec^2) higher than that found in the roundabout (0.33 m/sec^2). Overall, considering both indicators, the best safety conditions occur in the roundabout.

Conclusions

In this paper the validity of a microscopic framework to identify potentially unsafe vehicle interactions is investigated. For this purpose the authors developed a microscopic simulation model (TRITONE) that, through a specific module, identifies anomalies in driver behavior that may be the cause of crash occurrences. In particular, this microscopic simulation model has been calibrated and applied to a two-lane undivided rural highway in order to analyze traffic safety conditions in terms of three safety performance indicators (DRAC, TTC and PSD). Once the micro-simulation software has been calibrated, this software has been applied to two different contexts. In particular, the safety performance conditions (in terms of TTC and DRAC) of a four-entries intersection regulated by stop sign (Scenario A) and of a roundabout with the same number of entries (Scenario B) have been evaluated. Through this application it was possible to assess how the conversion of a stop sign controlled intersection into a roundabout led to a reduction of the number of interactions between vehicles improving safety performance.

The results underline how the approach adopted to analyze road safety can be a useful instrument for investigating crash occurrences and/or near misses. The most used microscopic simulation models within the scientific community have not included a specific module to analyze crash occurrences and near misses, and thus these models can only replicate disruptive driver behaviors with a certain level of accuracy and detail. The development of more complete microscopic traffic algorithms, that account for a wider range of behavioral attributes related to misjudgments of speed and distance or incorrect decisions, due to inexperience and motivational factors, constitutes a valid support for adopting the microscopic simulation in safety studies.

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