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APPLICATION AND COMPARISON OF DIFFERENT METHODS FOR TRAFFIC CONFLICT ANALYSIS – CASE STUDY ON 2+1 ROADS

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Safety Performance Functions and Crash Modification Factors are statistically-based prediction methods that require significant efforts and long periods in crash data collection. Traffic conflict studies can mitigate this issue using a short time survey to measure the number and severity of traffic conflicts, which are regarded as surrogate safety measures. Unfortunately, they are empirical studies that can be carried out only after the implementation of a treatment. The overall objective of the present research is to investigate the performance of different methods for conflict detection and classification, considering the observed conflicts on 2+1 roads in Poland. Observations were compared with conflicts detected in simulated environments. The latter include either the Agent-Based Microsimulation (ABM) approach, or the virtual reality simulation using a Driving Simulator (DS). Conflicts were detected and classified based on video recording and analysis of vehicle trajectories in the merging area of 2+1 roads. The studies focused only on lane-changing conflicts. Locations, Post Encroachment Time and Time to Collision values of observed conflicts between vehicles were subsequently identified. Observed conflicts were compared with the ones resulting from ABM and DS, to determine whether there is a correlation between them.

Keywords: surrogate measures of safety, road safety, SSAM, passing lane, 2+1 road

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1. INTRODUCTION

Improving the safety and operational performance of new highway design from observational data is a reactive approach that requires a suitable sample of sites and a historical evaluation. So far as the safety performance is concerned, Safety Performance Functions (SPFs) and Crash Modification Factors (CMFs) are statistically-based prediction methods that require significant efforts in crash data collection, and long periods of crash occurrence observance. Proactive approaches to assess road safety [1], including traffic conflict studies, can mitigate this issue using a short time survey to measure the number and severity of traffic conflicts, which are regarded as surrogate measures of safety. Unfortunately, they are again field-based studies that can be carried out only after the implementation of a treatment. Moreover, the international transferability of existing studies is another issue that limits the predictability of future performances [2]. This is the case when evaluating the safety performance of new design schemes or treatment typologies, such as the design of 2+1 lanes in Poland, which is the aim of the present research.

Nowadays, Agent-Based Microsimulation (ABM) is a well-established tool for analyzing the operational effects of new or complex geometric schemes [3]. More recently, studies [4] have attempted to use microsimulation vehicle trajectories to classify traffic conflicts, as well. Specifically, traffic conflicts can be detected through the Surrogate Safety Assessment Model software (SSAM) [5] where vehicle trajectories obtained from microsimulation software (e.g. VISSIM) are post-processed. The application of microsimulation conflicts is considered as one of the methods that are based on surrogate safety measures, which permit the estimation of the number of conflicts for different road and traffic configurations [6], [7], [8], [9], [10]. Such an approach is much more popular when analyzing intersections and, although simulation modelling of road sections with additional lanes has been described in the literature, these studies mainly discuss modelling in the context of evaluating operation and traffic performance [11], [12], [13].

In a similar manner, but focusing on the human factor, one of the most effective tools for analyzing driving behavior using an interdisciplinary approach, which can evaluate interactions between driver, vehicle and road environment, is the driving simulator (DS) [14], [15]. The driving simulator permits to investigate the variability of the driver's behavior under different conditions (e.g., geometries and traffic flow), thus offering a very promising perspective for road safety design and management; this advanced technology overcomes some of the typical problems related to field studies (e.g., safety, cost, experimental control) and allows, at the same time, the collection and processing of continuous speed and trajectory profiles. Moreover, experiments can be developed in a controlled environment and under pre-established conditions that are replicable to all participants, concerning driving performance and surrogate safety measures, interactions between drivers and road features, especially the geometric characteristics of the road alignment and traffic conditions. Finally, several validation studies [16], [17] have demonstrated that this tool provides the driver with enough visual information to allow him or her to correctly perceive speeds and distances.

Moreover, despite the well-known potentialities of these software tools, care has to be taken regarding the appropriateness of microsimulation and the driving simulator in reproducing real-like outcomes of traffic conflicts. Therefore, model calibration and validity of the results should be carefully considered.

In this framework, the present research work deals with alternate passing lanes that differ from the traditional 2+1 schemes due to the limited number of segments with an added lane (usually, one per direction). In Poland, the approach is to build alternate 2+1 passing lanes and to preserve long two-lane sections between 2+1 road sections [18], [19]. The reasons for the application of such design in Poland relates to the high density of intersections and built-up areas, as well as budget constraints for any comprehensive reconstruction of the entire road network. Short passing sections can limit the main functions of longer 2+1 sections, i.e. the ability to disperse traffic platoons; this may lead to hazardous maneuvers like aggressive lane changing, and to an increase in the number of conflicts around the critical merging area at the end of the 2+1 section.

Starting from microsimulation scenarios calibrated according to operational parameters, and from the same scenarios replicated and tested in a driving simulator environment, the present research work deals with the validation of simulated conflicts against observed conflicts. At this stage of the research, the paper focuses mainly on video recording and evaluation, to obtain observed conflicts from digital image software analysis, vehicle tracking, and algorithms, and to depict the conflicts on real-like 2+1 sections. The observations were conducted at 5 locations with different geometric designs and traffic flows. Microsimulation in the VISSIM software was carried out, and SSAM conflicts were then identified and counted, whilst driving simulator scenarios were calibrated at 2 of those locations, as well. The present study, is the next step of 2+1 road safety research conducted by authors [20] which include in the analysis the use of driving simulator. The methodology part as well as the previous result are reported for sake of completeness and updated with the new research conducted here.

2. METHODOLOGY

A comparison of observed and simulated conflicts requires an empirical study, microsimulation modelling, and a driving simulator research. Observed conflicts were calculated based on video observations and digital frame analysis to detect vehicle positioning within the frames. A microsimulation model was developed using the PTV VISSIM software. For the calculation of conflicts based on trajectories obtained from microsimulation, the SSAM software was used. Driving simulator data was collected using a fixed driving simulator at the Road Safety Laboratory of the Engineering Department at Roma TRE University (LASSTRE).

2.1. OBSERVED CONFLICTS [20]

Observed conflicts were gathered during a survey campaign on different 2+1 segments in Poland at 3 locations under various conditions of geometry, traffic, the proportion of heavy vehicles and speed. The routes under investigation, located in the vicinity of Piaski, Zyrardow, and Krasnik (see Figure 1), had no separating median.

Fig. 1. Żyrardow (a), Kraśnik (b) and Piaski (c).

At each test site, camera locations were chosen to ensure an excellent view of the merging area and vehicle paths. Surveys were usually carried out during peak traffic hours (from 12:00 to 14:00) during weekdays (from Tuesday to Thursday).

The best locations were identified as the right-hand side of the merging area, at a distance of about 90-100 m from the start of the merging area, according to microsimulation results of conflicts [21]. In order not to affect the driver's behavior, the observer and equipment were not visible. Another factor that was considered was that the cameras were positioned at 4 to 5 m above the road level.

Table 1 presents the geometric characteristics of the additional lane selected for the video survey.

Each 2+1 segment was surveyed for at least 2 hours with a high-resolution camera.

Table 1. Summary of 2+1 sections characteristics.

Roadway*	Additional lanes length [m]	non-conflicting changeover length [m]	conflicting changeover length [m]
Zyrardow	1000	60	160
	800	60	160
Krasnik	1100	non-typical changeover	non-typical changeover
	1500	non-typical changeover	non-typical changeover
Piaski	1170	130	150
	850	130	130

**The sections consisted of grades in the ±2% range.*

As noted earlier, data gathering was made possible through video recordings of the different sections under investigation, which ranged in length between 85 and 100 meters from the point of conflict and had a width of 10.50 meters (Figure 2). Before starting the video recording, fixed points at the locations under study were taken as a reference and made visible on the frame. The distance between these fixed points was then measured to calibrate the software for data processing.

Fig. 2. Żyrardow (a), Kraśnik (b) and Piaski (c).

The actual procedure consisted of shooting videos that ranged between two and four hours, with a bit-rate of 25 frames/second.

2.2. CONFLICTS USING THE AGENT-BASED MICROSIMULATION

The development of the microsimulation model and the determination of the simulated conflicts are described in detail in [21]. To develop the microsimulation model, field empirical data were collected at 5 test sites on 2+1 road sections in Poland. The field observations were conducted during daylight, under good weather conditions, for a minimum of 4-5 hours, including peak hour periods. The lengths of the sections with the additional lane ranged from 550 m to 1000 m; the traffic volumes (calculated at 5-minute intervals) ranged from 240 to 1,116 veh/hour/dir. The sections were located on level terrain with vertical grade alignment lower than 3%. The data was collected with the help of pneumatic sensor traffic recorders and ANPR cameras (Automatic Number Plate Recognition). The field study documented driver behavior and traffic operation at the beginning and the end of the sections.

The microsimulation model was calibrated and validated. Calibration was aimed at obtaining a reliable share of platooning vehicles at the entry and exit of the passing lane in the simulated environment. Calibration was carried out on a section with a 1000 m passing lane. To perform calibration, the desired speed distribution of vehicles on the passing lane was regarded as a variable in the software, to make it match the observed distribution, as best as possible. The share of overtaking vehicles was taken as the validation parameter. Model validation was performed on data from the 800 m passing lane. For both calibration (1000 m) and validation (800 m) sections, the share of overtaking vehicles was lower than 10% [20].

Traffic conflicts were estimated by SSAM software using microsimulation trajectory outputs of VISSIM, following calibration and validation. The analysis focused on lane-changing conflicts. The conflicts were estimated for Time to Collision (TTC) and Post Encroachment Time (PET), for passing relief lane lengths varying between 500 m and 1200 m, with increments of 100 m. The simulations reported above, regarded the length of the merging area to be equal to 100 m.

2.3. CONFLICTS USING THE DRIVING SIMULATOR

The driving simulation tests were performed in the fixed-based driving simulator of the Road Safety Laboratory of the Engineering Department at Roma TRE University (LASSTRE). The system consists of a full cab Toyota Auris driving simulator with a force-feedback steering wheel, brake/accelerator pedals with 180-degree field of view projection. The system is typically used for evaluating driving performance in terms of speed, acceleration and trajectory under different driving conditions and road environments [22]. 2+1 segments of roads in Poland were exactly reconstructed in the simulated environment, along with the geometric characteristics, traffic conditions, markings, and signs (Figure 3).

Forty-five participants took part in the experiments (Figure 4 shows 2 phases of the test). Among them, three participants experienced some degree of discomfort and were not able to conclude the driving tests; the other two were excluded as statistical tests regarded them as outliers. Therefore, the final sample consisted of 40 drivers (27 men and 13 women) with a mean age of 25.8 years (SD = 6.8 years), ranging from 20 to 56 years.

Fig. 3. Examples of the 2+1 road segments in the real (on the left) and simulated (on the right) environment.

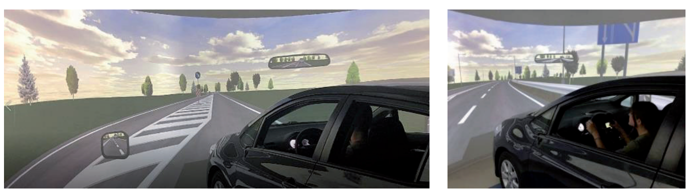

Fig. 4. Two different phases of the experiment using DS.

Although the driving simulator used in this study has already been validated on rural roads [15], [16], under different driving conditions and road geometries, its specific validation on 2+1 road configurations was highly recommended. Therefore, the first step in the analysis process consisted of comparing the speeds measured on-site with those recorded under simulation, at the beginning and the end of the additional lane of the 2+1 segment in Piaski. For each measurement site, there were two-speed samples, one obtained from field measurements (SR) and the other obtained from simulations (SS). Table 2 gives the sample size, the average speeds and standard deviations that were measured in the field, as well as those that were recorded using the driving simulator at the same locations. Noteworthy is that the speeds resulting from simulation (SS) were quite comparable to those collected in the field (SR). The differences between the average speeds (SR-SS) were only 2.33

km/h and 4.08 km/h, respectively. To affirm the reliability of the simulator, a bilateral Z-test for non-matched samples was used to ascertain whether the differences in average speeds between the two samples were statistically significant. The application of the Z-test was prompted by the Kolmogorov-Smirnov test of normality which proved that the distribution of speeds in the field and the driving simulator was normally distributed. The statistical analysis confirmed the outcomes of the comparative analysis on both sites, with a level of significance of 5%. In other words, it was found that the differences between the field speeds and the simulation speeds were not statistically significant, prompting promising results in the applicability of the research findings of the driving simulation experiments.

Table 2. Speed validation of the driving simulator on 2+1 roads.

Measurement point	Driving simulation		In-field		SR-SS	|Z|	Results
	n	μ (σ) [km/h]	n	μ (σ) [km/h]	μ (σ) [km/h]		
Beginning of the additional lane	35	86.00 (6.56)	23	88.33 (3.48)	2.33 (1.33)	1.76	Accepted
End of the additional lane	39	87.52 (11.56)	23	83.44 (3.09)	-4.08 (1.96)	2.08	Accepted

Various driving performances (speeds, accelerations, lateral/longitudinal positions, etc.) were collected. Specifically, the speed outputs and Post Encroachment Time (PET) were then analyzed and compared with data from field observations.

3. COMPARISON OF SIMULATED AND OBSERVED CONFLICTS

The microsimulation model and the driving simulator scenarios were calibrated using in-field data related to traffic operational parameters. As reported in the literature, simulated traffic conflicts estimated using different metrics have proven to be Surrogate Measures of Safety (SMoS) [21]. Given the preliminary data in the present study, comparisons were made between what was observed in the two simulated environments and what was noted in the field. Comparisons between the two simulated environments were not feasible due to the different metrics used in defining the conflicts; that is, TTC for the simulated conflicts in the ABM models and PET for the conflicts observed in the experiment using DS. As a further consideration, the frequency concept of the occurrence of traffic conflicts using DS is not a random event, inasmuch it is conditioned by the simulation environment parameters which do not have a random variability.

3.1. DATA TREATMENT

The analysis of observed conflicts is described in detail in Cafiso et al. [20]. Based on empirical research, 58 conflicts were identified in the 10 hours of video recording (Table 3), which were later compared with simulated conflicts. From Table 3, a large proportion of heavy vehicles, (50% in some cases), was noted. Each vehicle traveling on the passing lane, with lane-changing conflicts, was identified. Subsequently, a set of frames was analyzed separately by using an open-source software "Sputnik" [23] for vehicle tracking and positioning. The Sputnik output shows the position under different time frames (50 frames per second) of every vehicle (x, y) in the reference system.

The original output of vehicle trajectories showed considerable noise due to the detection and precision of tracking. Consequently, a filter was applied before any further elaboration of data was made. A simple moving average filter resulted in an effective smoothing of irregularities in the trajectories and speed profiles of vehicles. Other algorithms were applied to identify conflict points, TTC and PET, as reported in [21].

Table 3. Summary of 2+1 sections characteristics and number of observed conflicts [20].

Roadway	1-hour interval	Traffic volume ALL [veh/hour]	Traffic volume - Heavy vehicles [veh/hour]	number of conflicts
Zyrardow 1	1	471	274	8
		457	274	
	2	518	299	8
		450	263	
Krasnik 1	1	201	84	7
		185	103	
	2	219	94	11
		183	101	
Krasnik 2	1	198	84	0
		192	103	
	2	216	94	0
		188	101	
Piaski 1	1	407	99	14
		376	107	
	2	610	125	6
		381	105	
Piaski 2	1	345	92	2
		403	124	
	2	371	84	2
		395	121	
TOTAL	10	--	--	58

Based on the conflict maps, defined as the position of the conflict point at the minimum TTC, it is possible to note that the conflicts are more concentrated at the end of the merging lane and, as expected, are mainly located on the regular lane (Figure 5).

(a)

(b)

(c)

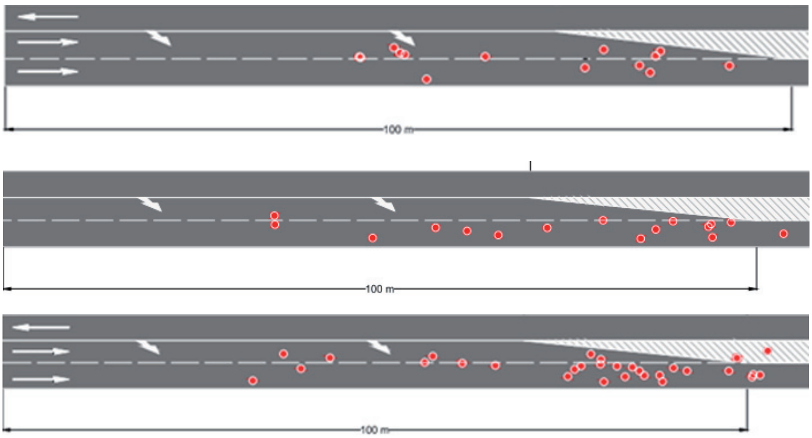

Fig. 5. Conflict map at Żyrardow (a), Kraśnik (b) and Piaski (c) [20].

3.2. COMPARISON OF FREQUENCIES OF OBSERVED AND MICROSIMULATION CONFLICTS [20]

To compare the observed and simulated conflicts, a regression analysis was performed on the number of simulated conflicts observed during 1 hour for different traffic flows and geometric characteristics [21]. SSAM conflicts were selected in the range of 1 to 5 seconds from the microsimulation models. As conflict occurrence and repetition follow the same probability distribution of crashes, like the crash number [2] it is possible to assume a negative binomial (NB) distribution of traffic conflict frequency. Therefore, a Generalized Linear Modelling with NB distribution [10] is a suitable tool for regression analysis. The regression is needed to estimate the conflicts under the same condition of traffic and section length of 2+1 sections observed under real conditions. Particularly, based on observed 2+1 section data (Tables 1 and 3), 80 hours of simulated conflicts, with a length varying between 500 and 1200 m with increments of 100 m, and traffic flows ranging between 300 and 1200 veh/hour/dir with increments of 100 veh/hour/dir, were considered. Each simulation was run for 5 hours following a 30-min warm up time.

The model chosen is the following:

$$\frac{Conflicts}{hour} = e^{\alpha} \cdot Q^{\beta} \cdot L \tag{3.1}$$

where:

L – length of additional passing lane [m], Q – traffic volume [veh/hour/dir], α, β – regression coefficients

Following model calibration, regression analysis yielded significant coefficients (see Table 4), thus maximizing the log-likelihood function. As can be observed from Table 4, the Pearson Chi-square statistic is regarded as small enough to provide an assessment of the fair goodness of fit (g.o.f.) of the regression model to the data.

Table 4. Regression Parameters and g.o.f. for Equation 1 [20].

	Coeff.	Stdev	P-Value
(Intercept) α	-30.7971	1.1707	<.0001
(Traffic) β	3.9886	0.1710	<.0001
Dispersion parameter k	0.0542	-	-
Scaled Deviance (SC/DF*)	68.71 (0.88 DF=78)		
Pearson Chi-square (Chi-square/DF)	78.0620 (1.0008 DF=78)		

Real-world conflicts identified by the video analysis were compared to the simulated ones under the same geometric and traffic conditions. A straight linear correlation was obtained between the observed and simulated number of conflicts, with a ratio of 10 real conflicts for each simulated one (Figure 6). Data in Figure 6 was clustered by sites (reported in paragraph 2.1). Each point represents the average value of each site. The regression coefficient was very high, with an R2 value of 0.8.

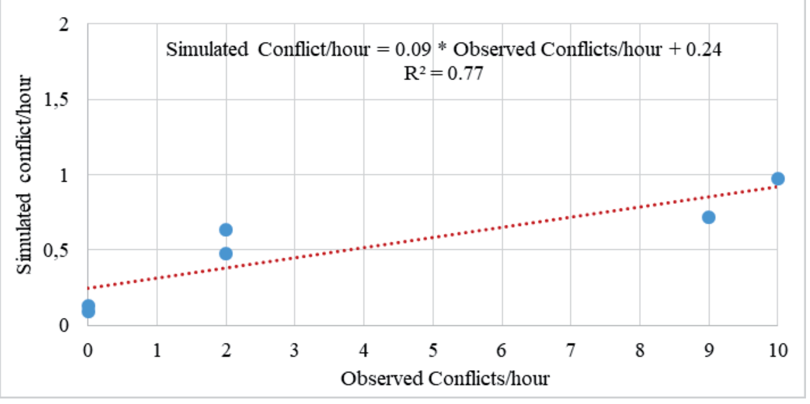

Fig. 6. Regression analysis of observed conflicts/hour vs. simulated conflicts/hour [20].

The reduced number of simulated conflicts should be related to the more strict observance of the merging lane rules under simulation when compared to the real-world driver behavior. That result indicates that more aggressive driver behavior is to be set under microsimulation to increase the number of conflicts. So far as conflict severity is concerned, other candidate parameters for microsimulation calibration and validation are needed, such as the values of TTC and speed, which may be used when comparing simulated and real-world conflicts in the calibration process. In the VISSIM lane-changing behavior, driver aggressiveness can be controlled by modifying the maximum deceleration rates, and by reducing the deceleration rate as the vehicle approaches the merging point [18]. Modifications of the maximum deceleration rates for merging and trailing vehicles, as well as for car following headways may be conducted to determine the effect on the number and severity of traffic conflicts.

3.3. COMPARING THE DISTRIBUTIONS OF PET VALUES FOR OBSERVED AND SIMULATED CONFLICTS USING DS

Comparing the conflicts detected using DS to the observed ones cannot be made by relying solely on frequencies, as was carried out with microsimulation, simply because every test on the driving simulator produces a conflict in the merging area for which the PET value was computed. The frequency of conflicts detected using DS is equal to the number of tests performed in the experiment. The selection of conflicts to be compared with the observed ones was made based on the PET value. The threshold used was 3.5 seconds; it included 99% of the detected conflicts. To obtain a larger sample size, all of the observed conflicts were used (at 3 different locations) to determine their cumulative frequency distribution; the experiment using DS included only 2 of those and which were regarded as independent. The comparison was performed in terms of cumulative frequency distribution (Figure 7).

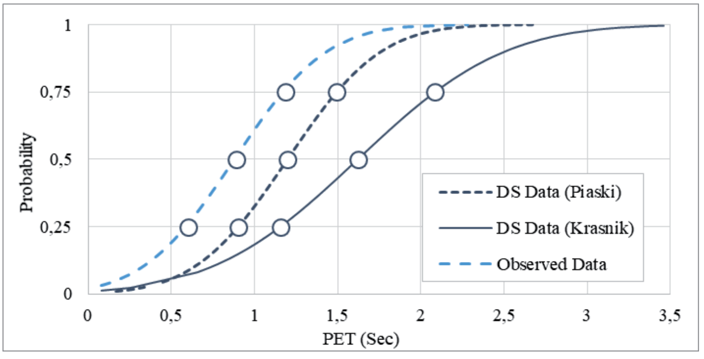

Fig. 7. Cumulative distribution of PET values for observed and simulated conflicts using DS.

The cumulative frequency was calculated by taking into account the normal distribution and the means and standard deviations of the samples, from the observed data and DS. Although the PET distribution in Krasnik is not similar to the observed data, the Piaski PET distribution has a fixed offset compared to the cumulative frequency distribution of PET on all observed sites. The lowest values of PET are obtained from the observed data. The value of PET is lower than that suggested in SSAM [5].

4. CONCLUSIONS AND FUTURE RESEARCH WORK

The paper reports ongoing research work to explore different approaches to assess traffic conflicts based on empirical data and simulated environments. It is the next step of a previous research of authors with the inclusion of the DS study. The objective of the study was the merging area on 2+1 roads.

Microsimulations, as well as video surveys and DS scenarios, were performed on typical Polish 2+1 segments. A total of 10 hours of video recording were analyzed for conflicts evaluation on the merging areas of five 2+1 segments with different traffic conditions and lengths of the passing lane. The video was analyzed frame-by-frame at 50 Hz, and vehicle trajectories were identified by imaging software to eliminate image distortion by recording real measurements of fixed points in the frames. A part of the software's accuracy, data filtering and results validation has been used to avoid false positives in conflict detection and TTC and PET evaluation.

Previously calibrated microsimulation models with traffic control parameters were used to create virtual vehicle trajectories analyzed by SSAM to identify conflicts in the simulation environment. Comparison of simulated and observed conflicts, even in the early stages of this study, shows a significant linear correlation, but with a factor of 1/10 between the simulated and the actual number of conflicts. This difference is probably due to the different techniques of conflicts detection and analysis, which are much more effective (for simulated conflicts) in intersections. For road segments, similar research is limited in number and in lane change maneuvers in merging areas. In this case, the frequency of the conflicts was identified with the same threshold of TTC value equal to 5 seconds for both observed and simulated conflicts.

This difference in the total number of conflicts is not necessarily a problem since the sensitivity of the number and severity of conflicts to changes in traffic conditions and geometries of the 2+1 section is primarily important for calibrating microsimulation for safety performance analysis of alternative design systems.

The DS experiment was set at 2 different locations (4 different 2+1 merging areas), with 40 drivers each. In this case, the comparison with the observed data could not be made based on the frequency of conflicts, but the PET distribution was used. The use of PET instead of TTC is due to simple computation that does not require a motion prediction phase for trajectories and speeds after detecting evasive maneuvers. The results are encouraging in Piaski's case, there is only a 0.3 second shift between the observed conflicts and the conflicts observed in the driving simulator experiment.

One of the reasons for the different values and shapes of cumulative distributions may be the type of separation between opposite travel directions. For Krasnik, this was a double solid line, and for Piaski, the physical separation consisted of poles (0.8 m in separation). The presented results are still in a preliminary phase due to the small sample size of the observed data.

However, the results of the study are promising and reveal the potentiality of using microsimulation and driving simulator approaches to study vehicle interactions and estimate the frequency of traffic conflicts based on different Surrogate Measures of Safety (SMoS). A comparison of the different methods is important because the evaluation of conflict types (ie, lane change, rear-end conflicts based on TTC and PET) is unclear. Thresholds, therefore, need to be defined for the different methods of conflict estimation, since their numbers and SMoS values differ significantly from one approach to another. This is primarily identified by the microsimulation method, where higher SMoS values are observed and a similar conclusion can be drawn from the SMoS obtained from the driving simulator experiment.

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ZASTOSOWANIE I PORÓWNANIE RÓŻNYCH METOD ANALIZY KONFLIKTÓW RUCHOWYCH – STUDIUM PRZYPADKU DROGI 2+1

Słowa kluczowe*: pośrednia miara bezpieczeństwa ruchu, bezpieczeństwo ruchu, SSAM, pas do wyprzedzania, droga 2+1*

Statystyczne metody przewidywania zdarzeń drogowych, takie jak modele regresyjne (SPF) czy współczynniki zmian liczby zdarzeń drogowych (CMF) wymagają długich okresów gromadzenia danych o zdarzeniach oraz dużych nakładów finansowych w przypadku oceny efektywności środków poprawy bezpieczeństwa ruchu drogowego lub zmian w infrastrukturze drogowej. Jednym ze sposobów badań niwelujących wyżej wymienioną niedogodność są analizy bezpieczeństwa ruchu za pomocą miar pośrednich, jakimi są np.: zmiana liczby konfliktów w ruchu drogowym obserwowanych lub symulowanych. Analiza konfliktów obserwowanych pozwala na ocenę bezpieczeństwa ruchu na podstawie krótkiego okresu obserwacji i oceny ich liczby oraz ciężkości. Jednakże, ocena bezpieczeństwa ruchu na podstawie konfliktów obserwowanych jest badaniem empirycznym, które można przeprowadzić dopiero po wdrożeniu środków poprawy bezpieczeństwa ruchu lub zmian w infrastrukturze, co jest kosztowne. Środkiem łagodzącym wyżej wymienione wady jest ocena bezpieczeństwa ruchu na podstawie konfliktów symulowanych. Zastosowanie w ocenach bezpieczeństwa ruchu konfliktów symulowanych wymaga znajomości związku pomiędzy konfliktami obserwowanymi i symulowanymi. Celem przedstawionych badań jest ocena różnych metod wykrywania i klasyfikacji konfliktów ruchowych, w odniesieniu do obserwowanych konfliktów na drogach 2+1 w Polsce. Konflikty obserwowane były wykrywane i klasyfikowane na podstawie nagrań wideo i analizy trajektorii pojazdów w obszarze włączenia pasa do wyprzedzania na końcu odcinka drogi 2+1. Badania koncentrowały się wyłącznie na konfliktach powodujących zmianę pasa ruchu. Tak uzyskane konflikty były porównywane z konfliktami wykrytymi w środowiskach symulowanych. Konflikty symulowane były analizowane na podstawie podejścia mikrosymulacyjnego (ABM) oraz symulacji rzeczywistości wirtualnej przy użyciu symulatora jazdy (DS). Oba modele, tj.: mikrosymulacyjny jak i w symulatorze jazdy zostały skalibrowane na podstawie empirycznych badań ruchu pojazdów w środowisku rzeczywistym. Konflikty symulowane w środowisku mikrosymulacyjnym były oceniane na podstawie trajektorii pojazdów uzyskanych z wcześniej zbudowanego modelu w programie VISSIM oraz ich analizy w narzędziu Surrogate Safety Assessment Model (SSAM). Badania te były realizowane w ramach wcześniejszych prac autorów. Badania konfliktów w symulatorze jazdy przeprowadzono na podstawie rzeczywistego przebiegu dwóch poligonów badawczych na Uniwersytecie Roma Tre w Rzymie. Na podstawie badań zidentyfikowano, dla warunków rzeczywistych i symulowanych, lokalizacje konfliktów, wartości czasu po wtargnięciu (PET) i czasu do kolizji (TTC) obserwowanych i symulowanych konfliktów między pojazdami. Obserwowane konflikty porównano z konfliktami oszacowanymi w środowisku mikrosymulacyjnym i w symulatorze jazdy, aby określić, czy istnieje między nimi związek pozwalający na ocenę wpływu zmian w infrastrukturze drogowej na bezpieczeństwo ruchu.

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