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Research paper

Type II dilemma zone at high-speed signalized intersections in Poland

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Abstract: Red-light running at intersections is a common problem that may have severe consequences for traffic safety. The present paper investigates driver behavior in dilemma zones in Polish conditions. Based on the empirical research conducted at 25 urban and rural signalized intersections, type II dilemma zone boundaries were determined. In this study, generalized linear regression models were used to fit the probability of stopping to explanatory variables. Seeing as the dependent variable is dichotomous (stop/go), binary logistic regression was used for predicting the probability of the outcome based on the values of continuous or categorical predictor variables. The results show that factors which have a statistically significant effect on drivers' propensity to stop include: vehicle type, the geometry of the intersection, location of signal heads and platooning on the approach to the stop line. Type-II dilemma zone boundaries are situated at the following distance: the beginning from 1.9 s to 2.4 s, and end from 5.0 to 5.9 s (on average 2.2 ÷ 5.4 s) from the stop line.

Keywords: signalized intersection, road safety, dilemma zone, driver behavior

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1. Introduction

Traffic signals are a popular and effective tool for improving road safety. They aid in the reduction of collisions between vehicles as well as vehicles and pedestrians due to temporal and spatial separation of conflicting vehicle trajectories. However, reed-light running is a major safety concern resulting in collisions between vehicles and other road users. In the USA, 20% of crashes at signalized intersections are red-light running-related [1, 2]. A similar share is reported in Poland [3], where 1350 injury crashes were recorded between 1st January 2017 and 31st December 2019 [4] (620 victims per year). Red-light running often leads to injury crashes and higher-severity collisions [5].

Rear-end and angle collisions are the most common type of crashes occurring at signalized intersections. At high-speed signalized intersections in Poland their share is respectively: 26% and 48% [3]. Both of these types of crashes are related to the period when the light changes from green to yellow. Drivers approaching the signals and facing a yellow signal, have the choice to either decelerate and stop or continue and cross the intersection. Oftentimes, the decision made turns out to be the wrong one: when a driver decides to brake suddenly on approach to the intersection, this may cause a rear-end collision, while drivers who are still far away from the stopping line and who decide to clear the intersection run the risk of causing an angle collision within the intersection. These situations may be described as the "dilemma zone" problem. The literature distinguishes two types of dilemma zones:

- Type I (kinematic) – when drivers cannot stop in time for the red indication without uncomfortable braking, and also cannot safely clear the intersection during intergreen interval,
- Type II (probabilistic) – which describes drivers' decisions uncertainty in response to the yellow signal.

Type I dilemma zone (DZ-I) has been studied since the 1960s [6] and is well described in the literature [1, 3]. DZ-I is used to determine the duration of the yellow interval adjusted to the speed limit at a given intersection. Unlike Type I, Type II dilemma zone (DZ-II) has not been analyzed in detail in Polish conditions, even though the ability to predict the drivers' decisions in response to the yellow indication is necessary to develop robust signal control algorithms, improve geometric design and intersection equipment aiming to increase road safety. Reliable recognition of factors influencing drivers' decisions in the dilemma zone is necessary due to the implementation of Intelligent Transportation Systems (ITS) and systems supporting decision-making managers (eg. Green Light Optimized Speed Advisory system) or developing Vehicle to Infrastructure and

Vehicle to Vehicle communication. Drivers' decision models are necessary to calibrate simulation models dealing with intersection safety [7].

The main objectives in this paper are:

- to determine the behavior of drivers approaching an intersection when the green signal ends,
- to determine the factors influencing the stop/go decisions of drivers with particular attention on the characteristics of the intersection geometry and its surroundings,
- to determine the probabilistic dilemma zone boundaries in Poland.

Properly recognizing driver behavior associated with the signal change at signalized intersections is crucial for improving road safety through better design or adaptive signal control strategies adjusted to human behavior.

2. Probabilistic approach to the dilemma zone

The probabilistic dilemma zone (also known as indecision zone) describes the probability of stopping in reaction to green changing to yellow. Zegeer [8] following Parsonson [9] assumed the beginning of the zone as occurring at the position where 90% of drivers decide to stop, and the end of the zone as occurring where only 10% of the drivers stop. The dilemma zone boundaries may be defined in terms of the travel time to the stop line [8, 9, 10, 11] or distance to it [12, 13]. Approximate boundaries are reported from 2.5 to 5.5 s.

Important drawbacks of the probabilistic dilemma zone are technical difficulties related to the designation of its boundaries, and the fact that its computation is time-consuming. The most common measuring method is video recording of the approach segment and a lab analysis of the footage [10, 11, 13, 14].

Sheffi and Mahmassani [14] proposed the use of probit regression to estimate the probability the vehicle stopping in order to shorten the time of measurement by reducing the number of required observations. Nowadays, binary logistic regression is used much more often [10, 15, 12, 16, 17].

The factors determining the drivers' decisions mainly concern the human factor, the current traffic volume and signal control strategies. The geometry of the intersection and approach section as well as traffic control are determining factors which are used infrequently in analyses. At the same time, the geometry and equipment of intersections prove to be important factors influencing the frequency of crashes associated with traffic signals.

3. Probabilistic dilemma zone in Polish conditions

3.1. Empirical research

Vehicles were recorded on intersection approaches using several video cameras installed between 160 m and 20 m before the stop line. The research was conducted at 25 approaches – 13 urban intersections located in Kraków with a raised speed limit of 70 km/h, and at 12 rural signalized intersections. The selection of intersections was determined by the need to ensure variety in terms of geometry, traffic volume, speed distribution at approach as well as the equipment of the intersection and its vicinity.

The following characteristics at each intersection approach and approaching vehicles were collected: signal indication, driver's stop/go decision, speed and distance to the stop line, vehicle type and platooning. During processing, only first-to-stop and last-to-go vehicles were analyzed.

3.2. Logistic regression model

In this study, generalized linear regression models were used to fit the probability of stopping to explanatory variables. Seeing as the dependent variable is dichotomous (stop/go), binary logistic regression is a useful technique for predicting the probability of the outcome based on the values of continuous or categorical predictor variables. The binary logistic regression model has the following form:

$$p = P(Y = 1 \mid x_1, x_2 \dots x_k) = \frac{e^{\beta_0 + \sum_{j=1}^{k} \beta_j x_{ji}}}{1 + e^{\beta_0 + \sum_{j=1}^{k} \beta_j x_{ji}}} \tag{3.1}$$

where:

p – is the probability of variable y_i taking on value 1 (success – when analyzing a case of vehicle stopping),

β_j –parameters of the model for $0 \le j \le k,$ where β_0 is an intercept parameter, x_{ij} – the observed value of the explanatory variables for i-th observation

Therefore, the binary logistic regression model estimates the probability that a characteristic is present (here: the driver decides to stop) given the values of explanatory variables, in this case a single categorical variable. The explained variable p takes on values from the range [0, 1]. Application of a logit function as a link function guarantees a codomain on the same range.

A characteristic parameter used in logistic regression is the odds ratio (OR), which denotes the ratio of “success” to “failure”:

$$OR = \frac{p}{1-p} \tag{3.2}$$

In the assessment of the relevance of parameters (or groups of parameters), the Wald test was used with the following formula:

$$W = \left(\frac{\beta_j}{\sigma_{\beta j}}\right)^2 \tag{3.3}$$

in which:

$\sigma_{\beta j}$ – standard error of the estimator, β_j – independent variable j.

As measures of model fitting, McFadden’s index R_F^2, deviation statistics σ_{df} and weighted Pearson’s statistics χ^2 $S_{\chi 2}$ were used. To detect outliers, Cook’s distance was used.

3.3. Selection of independent variables

In order to describe the probability of the vehicle stopping/going in the dilemma zone, several variables were selected as independent variables. These included both quantitative and qualitative variables related to the geometry and vicinity of the intersection, traffic organization at the inlet and the current traffic at the time when the green signal ends. The focus was on intersection characteristic as factors whose influence is currently the least recognized. When selecting quantitative explanatory variables, those which had a too low coefficient of variation ($v < 0.2$) have been omitted, while when it comes to binary variables, it was assumed that odds ratio may not be less than 0.2. Table 1 contains all the characteristics of the analyzed variables.

The geometry of the intersection was described through a set of variables indicating the type of intersection (three- or four-leg), cross-section type, the presence of additional turn lanes (left and right), the presence of a median, and pedestrian crossings designated at the entry and exit of the analyzed direction of traffic. Quantitative geometric variables are shown in figure 1.

Table 1. Summary of the analyzed quantitative (Q) and qualitative (B) independent variables

Variable	Type*	Marking	Min	Max	Average
Location of intersection	B	*MZ_0_1*	0	1	–
Intersection surroundings urbanization degree	B	*SU_O*	1	3	–
Intersection equipment urbanization degree	B	*SU_W*	1	3	–
Intersection is located on the curve of the road	B	*CUR_0_1*	0	1	–
Number of lanes at the entry	Q	*L_p*	2	5	3
Total width of the lanes	Q	*S_w* [m]	7.0	17.0	11.8
Width of the entry (with hard shoulder)	Q	*S_j* [m]	7.0	17.0	12.4
Intersection surface	Q	*Ar* [m^2]	460	4000	1907
Longitudinal intersection depth	Q	*R_gl* [m]	32.5	80	54.4
Transverse intersection depth	Q	*R_pop* [m]	24.3	83	51.3
Elongation factor	Q	*Wsp_R* [-]	0.76	1.67	1.10
Perceived longitudinal depth	Q	*R_gl_p* [m]	13.3	53	35.4
Distance between the side approach and the axis of the analyzed lanes	Q	*R_pop_p* [m]	9.5	37.0	20.5
Distance between the stop line and the edge of the nearest conflict zone	Q	*R_kon* [m]	13.0	41.4	23.4
Approach grade	B	*i* [%]	–2.80	2.80	–0.40
Approach on the right-hand side	B	*WLP_0_1*	0	1	–
Left turn only lane	B	*WL_0_1*	0	1	–
Right turn only lane	B	*WP_0_1*	0	1	–
Pedestrian crossing at the approach	B	*PLZ_0_1*	0	1	–
Pedestrian crossing at the exit	B	*PPZ_0_1*	0	1	–
Intergreen time for clearing stream	Q	t_m [s]	3	14	–
Number of signal heads for through movement	Q	*N_sg_rel* [-]	2	5	3
Number of signal heads at the approach	Q	*N_sg_wl* [-]	2	7	5
Distance from the signal heads to stop line	Q	*L_sg* [m]	8.0	20.5	11.3
Lane used by the vehicle	B	*Pas*	1	3	–
Vehicle type	B	*LC_0_1*	0	1	–
Vehicle speed	Q	v_0 [km/h]	30.6	140.9	70.1
Distance from the stop line	Q	x_0 [m]	5.5	248	72.1
Travel time to stop line	Q	t_0 [s]	0.3	11.6	3.7
Vehicle is following another vehicle	B	*FV_0_1*	0	1	–
Vehicle is followed by another vehicle	B	*LV_0_1*	0	1	–
Q – Quantitative variable, B – qualitative variable					

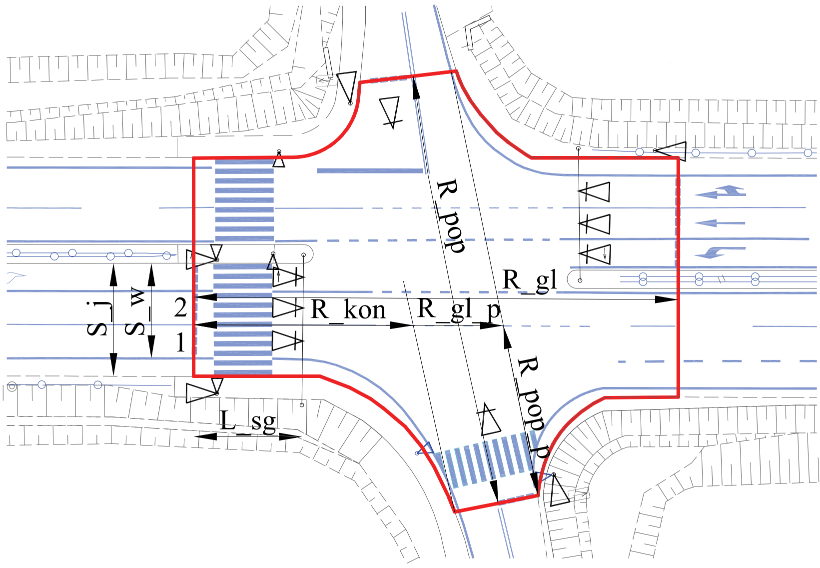

Fig. 1. Parameters describing the geometry of the intersection

The characteristics of the test sites also included signal heads placement, described by their number at the entry and the distance of the signal heads over the lanes from the stop line. In order to eliminate variables correlated with each other from the model, Pearson's correlation coefficient was used, while for qualitative variables Cramer's V coefficient was used.

4. Model outputs

In order to develop the model, the stepwise forward method was used. This technique was used for alternative sets of independent variables. In the model, the position of the vehicle in relation to the stop line was represented by the distance expressed by travel time t or distance expressed in meters and speed at the time when the green signal ends. The assessment of the significance of the parameters was carried out based on Wald statistic χ^2, with the significance level $p = 0.05$. The results of the statistical analysis are summarized in Table 2.

The explanatory variables which proved to be significant include:

- the distance of the vehicle from the stop line (x_0 or t_0),
- vehicle speed v_0,
- the type of vehicle *LC_0_1*,
- the presence of a vehicle ahead *LV_0_1*,
- the presence of a vehicle in close proximity to the analyzed one *FV_0_1*,
- location of the intersection *MZ_0_1*,

- the distance from the signal heads to the stop line *L_sg*,
- the presence of a left- or right-turn only lane at the approach *WL_0_1*, *WP_0_1*.

Table 2. Regression models of drivers' decisions

t	b_0	t_0	x_0	v_0	*L_sg*	*LC_0_1*	*FV_0_1*	*LV_0_1*	*MZ_0_1*	*WL_0_1*	*WP_0_1*
β_i	–6.677	1.424	–	–	0.070	–0.339	–0.251	–0.269	0.241	–0.147	0.089
σ	0.278	0.037	–	–	0.018	0.058	0.065	0.071	0.043	0.050	0.044
W	575.3	1451.6	–	–	15.4	34.7	14.7	14.6	30.9	8.6	4.2
p	0.000	0.000	–	–	0.000	0.000	0.000	0.000	0.000	0.003	0.041
	S.χ^2 =	8.75	–	*Log* =	–1996	–	R_F^2 =	74.6%	–	ZR^2 =	84.5%
x	b_0	t_0	x_0	v_0	*L_sg*	*LC_0_1*	*FV_0_1*	*LV_0_1*	*MZ_0_1*	*WL_0_1*	*WP_0_1*
β_i	–1.300	–	0.073	-0.078	0.076	–0.324	–0.236	–0.262	0.207	–0.116	0.141
σ	0.294	–	0.002	0.003	0.018	0.057	0.064	0.070	0.048	0.048	0.044
W	19.6	–	1448.5	509.1	18.3	32.1	13.6	14.1	19.0	5.7	10.4
p	0.000	–	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.017	0.001
	S.χ^2 =	1.34	–	*Log* =	–2054	–	R_F^2 =	73.9%	–	ZR^2 =	84.2%
	β_i – independent variable coefficient						S.χ^2 – chi-squared statistic				
	σ – standard error						Log – logarithm of likelihood function				
	W – Wald statistic						R_F^2 – McFadden's pseudo R^2				
	p – significance level						ZR^2 – scored index R^2				

The presented variables are statistically significant, but they do not increase significantly the predictive ability of the model. To identify the impact of the individual factors on the decisions of drivers in the dilemma zone the developed models were used. The values of the odds ratio of a given parameter were compared in Figure 2. Increasing the distance to the stop line causes an increase in the likelihood of stopping. A similar effect is achieved by removing signal heads from the stop line. It is easier for a driver approaching the intersection to recognize the distance to the signal head located above the roadway than to the stop line.

When following another vehicle, the probability of continuing to go through the intersection is visibly higher. One can try to explain adjusting to the behavior of the driver ahead in terms of cognitive psychology (decision making in response to various incentives) or social psychology. What is easier to explain is an increase in the tendency to keep going when there is a concern that the vehicle following the analyzed vehicle might rear-end it. Although the impact of the leading and following another vehicle has already been observed [10], it has not yet been verified using statistical procedures. The presence of another vehicle following the analyzed one impacts to a similar extent the increase in the likelihood of going through the intersection as following a preceding vehicle. It should be noted that variables *FV_0_1* and *LV_0_1* indirectly represent traffic density.

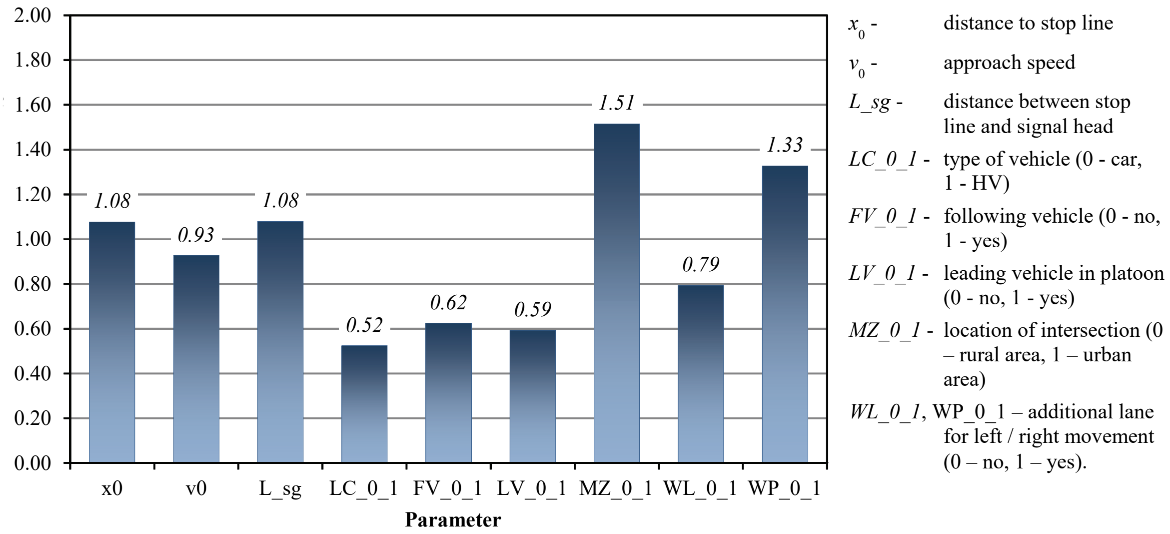

Fig. 2. Unit odds ratio for variables in *x*-model

In urban locations, the likelihood of stopping increases 1.5 times in comparison to locations outside built-up areas. Variable *MZ_0_1*, which is in principle a binary variable grouping intersections according to their location without additional classifying characteristics, proved to have a high explanatory capacity, despite the inclusion of a variable describing the speed v_0 in the model. The surrounding area of intersections in Kraków included in the measurement does not differ substantially from those outside of urban area. Perhaps this variable represents other characteristics that have not been tested in the model (traffic volume, number of stimuli, etc.)

Using the definition of dilemma zone by Zegeer, the type-II dilemma zone boundaries are situated at the following distance: the beginning from 1.9 s to 2.4 s, and end from 5.0 to 5.9 s (on average 2.2 ÷ 5.4 s) from the stop line. The length of the dilemma zone is constant at 3.1 s, and this is primarily the consequence of the form of the regression model. The beginning of the zone varies from 20 to 55 m depending on the speed of the vehicle (urban areas), while the ending varies from 69 to 153 m for rural areas. The length of the zone varies from 41 m to 89 m.

The developed models were compared with the models from other countries [10, 12, 18]. In order to preserve the consistency of data with the results of existing studies, the analysis was conducted for the speed v_0 <60.0, 70.0 kmh>. Figure 3 shows the probability of stopping in terms of distance to stop line for selected countries. The results obtained suggest more uncertainty of drivers' decisions on approach to intersections in Poland. In comparison to the results from Great Britain and the USA (for $t_z = 3$s), a greater share of drivers decides to go through the intersection. What is also noticeable is a larger share of stopping instances with a higher value of deceleration a_d (vehicles closer to the stop line are more likely to stop). Taking into account the signal control strategies and the duration of the yellow signal, drivers' decisions should be more similar to those of British drivers. A lower probability of stopping in Sweden is likely due to the widespread use of the LHOVRA system (it should also be noted that the Swedish results are the result of a measurement carried out at only one intersection). One can risk the hypothesis that the fixed length of the yellow signal does not lead to an increase in the uniformity of driver behavior, and may even be counterproductive if it is too short.

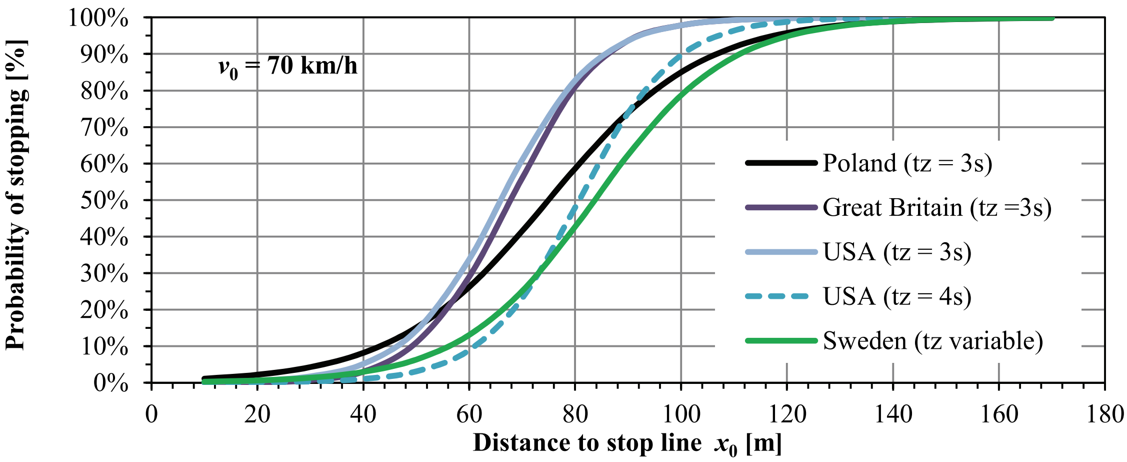

Fig. 3. Comparison of obtained results with selected models of the probability of stopping.

5. Conclusions

Type-II dilemma zone had not been previously analyzed in the Poland. If one refers the obtained results to the curves of the probability of stopping for similar circumstances (yellow signal length), it turns out that the range of the probabilistic dilemma zone in Poland is greater than by that in corresponding foreign models – the probability of entering the intersection in the first and the subsequent seconds of the red signal is higher. This may point to a specific behavior of Polish drivers on approach to intersections. A significant impact of the vehicle preceding and following the analyzed vehicle on the increase of the probability to go through has been noted. Geometry of the intersection and surrounding have minor impact on driver behavior. However urban and rural intersections should be analyzed separately – the probability of stopping is higher in an agglomeration.

The presented models of driver behavior in the dilemma zone provide a basis for the changes in the Polish traffic code as well as development of traffic control systems tailored to specifically Polish conditions. Comparison of the probability of stopping to other countries indicates the need to extend the yellow signal, which should be adapted to the speed.

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Strefa dylematu ii rodzaju na skrzyżowaniach z sygnalizacją świetlną o wysokich prędkościach w Polsce

Słowa kluczowe: skrzyżowanie z sygnalizacją świetlną, bezpieczeństwo ruchu, strefa dylematu, zachowanie kierujących

Streszczenie:

Sygnalizacja świetlna jest popularnym i skutecznym środkiem poprawy bezpieczeństwa ruchu na skrzyżowaniach. Wypadki na skrzyżowaniach tego typu często mają za przyczynę wjazd pojazdu na tarczę w trakcie sygnału czerwonego. W kraju udział wjazdów na sygnale czerwonym jako przyczyna wypadku na skrzyżowaniach z sygnalizacją wynosi ok. 20%, co oznacza przeciętnie 450 wypadków rocznie spowodowanych niedostosowaniem się kierujących do sygnałów świetlnych (ok. 620 ofiar na rok).

Innym typem zdarzeń przypisywanych sygnalizacji świetlnej jest najechanie na tył pojazdu, które powstaje w sytuacji, gdy pojazd poprzedzający decyduje się na zatrzymanie w reakcji na zakończenie fazy ruchu, a podążający za nim nie zareaguje, bądź zareaguje zbyt późno. Najechanie na tył poprzednika jest najczęstszym rodzajem wypadku, stanowiąc od 25% do 40% zdarzeń na skrzyżowaniach z sygnalizacją. Wymienione zdarzenia są związane głównie z okresem zmian sygnałów świetlnych (zielony – żółty). Kierujący zbliżający się do skrzyżowania podejmują decyzję, czy zatrzymać się, czy kontynuować jazdę przez skrzyżowanie. Kierujący znajdujący się zbyt blisko skrzyżowania decydując się na gwałtowne hamowanie, powodują ryzyko zderzenia tylnego, natomiast kierujący znajdujący się w znacznej odległości od linii zatrzymania kontynuując przejazd ryzykują zderzenie boczne na tarczy skrzyżowania. Zjawisko to określane mianem strefy dylematu może być opisane w ujęciu kinematycznym (strefa dylematu I rodzaju – występuje gdy droga hamowania jest dłuższa niż droga jaką może przebyć pojazd w czasie sygnału żółtego) lub probabilistycznym (strefa dylematu II rodzaju ï oznacza odcinek na wlocie, na którym nie można jednoznacznie przewidzieć decyzji kierującego w reakcji na zakończenie sygnału zielonego).

Głównymi celami badań opisanych w niniejszym artykule są wyznaczenie lokalizacji strefy dylematu w ujęciu probabilistycznym, w tym określenie zachowań kierujących zbliżających się do skrzyżowania w momencie zakończenia nadawania sygnału zielonego i ustalenie czynników wpływających na decyzje kierujących przejazd/zatrzymanie ze szczególnym uwzględnieniem cech skrzyżowania i jego otoczenia na podstawie obserwacji rzeczywistych zachowań kierujących.

Rejestrację decyzji uczestników ruchu w strefie dylematu przeprowadzono za pomocą techniki wideo i laboratoryjnej obróbki obrazu. Pomiar umożliwił określenie momentu przełączenia sygnałów, decyzji kierujących (zatrzymanie/przejazd), prędkości chwilowej oraz odległości od skrzyżowania pojazdu, jego typ oraz stan ruchu na wlocie skrzyżowania (obecność innych pojazdów na pasie). Ocenie podlegał ostatni pojazd kontynuujący przejazd i pierwszy zatrzymujący się. Pomiary przeprowadzono łącznie na wlotach 25 skrzyżowań cechujących się wysokimi prędkościami potoku pojazdów.

Do matematycznego opisu decyzji kierujących oraz ustalenia lokalizacji strefy dylematu w ujęciu probabilistycznym posłużono się uogólnionym modelem regresji liniowej (GLZ). Ponieważ zmienna objaśniana jest binarna (przejazd/zatrzymanie), wykorzystano regresję logistyczną. Do budowy modelu wykorzystano metodę krokową postępującą, przy czym technikę tę zastosowano dla alternatywnych zestawów zmiennych niezależnych. W modelu położenie pojazdu względem linii zatrzymania reprezentowane było przez odległość wyrażoną czasem dojazdu lub odległością wyrażoną w metrach i prędkością w momencie zakończenia sygnału zielonego.

Jako zmienne niezależne do opisu prawdopodobieństwa przejazdu/zatrzymania się pojazdu podejmującego decyzję w strefie dylematu wyróżniono szereg zmiennych ilościowych i jakościowych związanych z geometrią i otoczeniem skrzyżowania, organizacją ruchu na wlocie oraz stanem ruchu w momencie zakończenia nadawania sygnału zielonego. Cechy geometryczne skrzyżowania opisano za pomocą parametrów (zmienne jakościowe) określających typ skrzyżowania (trzy lub czterowlotowe), typ przekroju, występowanie dodatkowych pasów ruchu dla relacji skrętnych (w lewo oraz w prawo), obecność wyspy dzielącej, wyznaczenie przejść dla pieszych przez wlot i wylot analizowanego kierunku ruchu. Zmiennymi ilościowymi są cechy geometryczne, takie jak rozległość skrzyżowania: podłużna i poprzeczna, postrzegana rozległość skrzyżowania mierzona od linii zatrzymania do przedłużenia krawędzi jezdni poprzecznej, powierzchnia tarczy skrzyżowania. Do cech charakteryzujących poligony należał także sposób

rozmieszczenia sygnalizatorów opisywany przez ich liczbę na wlocie oraz odległość sygnalizatorów nad pasami ruchu od linii zatrzymania.

Do zmiennych objaśniających, które okazały się istotne należą:

- odległość pojazdu od linii zatrzymania,
- prędkość pojazdu,
- typ pojazdu,
- obecność pojazdu poprzedzającego,
- obecność pojazdu jadącego w bliskiej odległości za analizowanym,
- lokalizacja skrzyżowania,
- odległość sygnalizatorów od linii zatrzymania,
- występowanie pasa ruchu w lewo bądź w prawo na wlocie.

Przyjmując że granicę strefy dylematu wyznacza prawdopodobieństwo zatrzymania się wynoszące 10% i 90%, w wymiarze czasowym granice strefy dylematu II rodzaju zlokalizowane są w odległości: początek od 1,9 s do 2,4 s i koniec od 5,0 do 5,9 s (przeciętnie 2,2÷5,4 s) od linii zatrzymań. Długość strefy dylematu jest stała i wynosi 3,1 s. W ujęciu przestrzennym odległość dolnej granicy strefy waha się od 20 do 55 m w zależności od prędkości pojazdu (teren miejski), natomiast górnej od 69 do 153 m dla obszaru niezabudowanego. Długość strefy waha się od 41 m do 89 m.

Opracowane modele prawdopodobieństwa zatrzymania porównano z dostępnymi modelami z innych krajów. Uzyskane wyniki wskazują na większą niepewność decyzji kierujących zbliżających się do skrzyżowania w Polsce mimo stałej długości sygnału żółtego. Większy w porównaniu do wyników z USA i Wielkiej Brytanii udział kierowców znajdujących się w znacznej odległości od skrzyżowania decyduje się na kontynuację jazdy. Zauważalny jest też większy udział zatrzymań z wyższą wartością opóźnienia (pojazdy znajdujące bliżej linii zatrzymania częściej się zatrzymują). Biorąc pod uwagę sposób przełączeń sygnałów (działanie systemów sterowania ruchem) i długość sygnału żółtego, decyzje kierujących powinny być bardziej zbliżone do warunków brytyjskich.

Przedstawione modele zachowań kierujących w strefie dylematu stanowią podstawę do rozwoju systemów sterowania ruchem dostosowanych do specyfiki krajowej, a także wskazują na potrzebę zmiany sposobu ustalania długości sygnału żółtego na dostosowaną do prędkości na wlocie skrzyżowania.

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