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METHODOLOGY FOR RESEARCH ON TRAFFIC SAFETY AT SIGNALIZED INTERSECTIONS WITH COUNTDOWN TIMERS

Summary. The article is a presentation of the authors‘ research work on determining the impact of countdown timers on traffic conditions, and - in this case - on the level of traffic safety at intersections. Therefore, the scientific aim of the article is to present the methodology used by the authors to carry out research in order to determine the influence of the function of the intersection with countdown timers within an urban transportation network on the level of safety at the intersection. To achieve the scientific objectives, measurements of traffic at three intersections with different functions in a transportation network have been performed.

Keywords: countdown timers; traffic safety; signalized intersections; multilane intersections.

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1. INTRODUCTION

The use of countdown timers indicating the duration of individual signals at intersections with traffic lights is not permitted in Poland because it is not in accordance with [1]. However, the devices have been installed at some intersections in Polish cities, such as Cracow, Wrocław, Opole and Zabrze. Figure 1 shows photographs of existing equipment. In Figure 1a, the countdown timers at the intersection of De Gaulle and Roosevelt Streets in Zabrze are presented and, in Figure 1b, those at the intersection of Karkonoska and Zwycięska Streets in Wrocław are shown.

In the opinion of vehicle drivers and unprotected traffic participants, the use of countdown timers helps to ensure safe passage through the intersection. This has been proven by the research conducted by Kempa and Bebyn in Toruń [2]. Figure 2 illustrates the most important results of their survey conducted among vehicle drivers.

Similar studies were conducted in Bangkok on a sample of 300 drivers. More than 95% of these drivers identified perceptible benefits arising from the functioning of countdown timers, while it was also found that these results would encourage the Bangkok authorities to install them [3].

a) b)

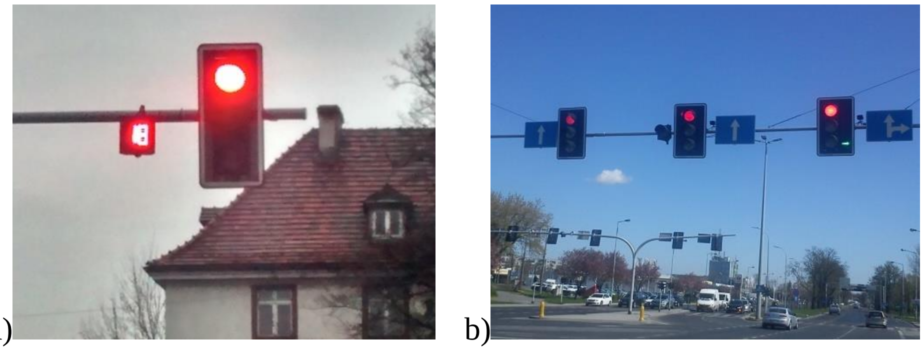
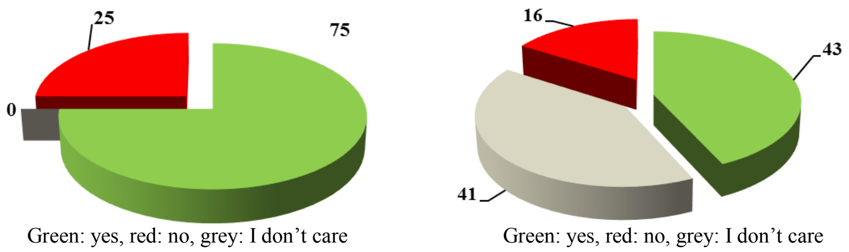


Fig. 1. Examples of countdown timers functioning at intersections in Poland



a) Structure of the answers to the question: "Do the countdown timers help you in safely passing through the intersection?"

b) The structure of the answers to the question: "Are drivers more disciplined (fewer entries on the red signal are observed) when countdown timers are functioning at the intersection?"

Fig. 2. The results of the survey carried out by Kempa and Bebyn
Source: [2]

Countdown timers are engineering solutions that are also controversial, especially in terms of ensuring an adequate level of traffic safety, as explained, for example, in [4-8] and pedestrian safety [9].

These studies in Poland focus on describing the defects of these devices, inter alia, in terms of construction and photometric requirements. They also discuss the presumption concerning the implications of the use of timers for dangerous behaviour of vehicle drivers.

Foreign studies on the functioning of countdown timers have been conducted, for example, in Kuala Lumpur as well as in other cities in Malaysia. The studies examine the impact of these devices on road safety and the assessment of their usefulness in terms of improving traffic conditions [10]. The measure to be tested was the average time interval between vehicles, which was about 10% shorter at intersections with functioning counters. In turn, the analysis of road safety was based on recording passes over the stop line at the red light with devices that were switched both on and off. In the first case, 24 passes were registered in 88 signalling cycles, while, in the other, 22 passes occurred of out 90 cycles (about three percentage points less) [10].

Other studies were conducted in Bangkok, where countdown timers have been introduced on a large scale (at about 400 intersections). Due to the long cycle times at most intersections in the city, the main purpose of the installation of these devices was to relieve the stress of drivers waiting for the green signal and to minimize the delay caused by inattention while waiting for the signal to change to green. The results of the research are summarized in [3], which focuses, for example, on the relation between the lengths of queues with countdown timers switched both on and off. This is also shown in Table 1.

Table 1

Lengths of queues at the intersection with countdown timers switched on and off

State of countdown timers	Number of registered cycles	Cycle times [s]	Time of green [s]	Length of queue [veh/230 s]
On	78	230	102	14-33
Off	78	230	102	14-37

Source: [3]

The issue of the use of the countdown timers has also been considered in [11-14]. However, it should be noted that the results of the studies conducted in Asian countries may not be comparable to those carried out in Europe due to the nature of the traffic.

2. INTERSECTION FUNCTION AND THE TYPE OF TRAFFIC

In Poland, the function of the intersection in transportation networks depends on the functions of the crossing roads, which are determined both by the road categories and their technical classes. Table 2 lists the categories of roads and their corresponding technical classes according to [15].

Each technical road class should comply with the relevant technical requirements (e.g., the minimum lane width for Class A roads is 3.75 m, but, for Class D roads, it is 2.5 m), which in turn define the functional requirements. In this way, the hierarchical structure of

the transportation network of the area is shaped. Therefore, according to the authors, both the road and the intersection may be divided in terms of functionality as follows:
- roads and intersections with non-urban traffic (most often national and voivodeship roads with a high proportion of trucks and trucks with trailers)
- roads and intersections with urban traffic (most often district and municipal roads characterized by a dominant and high share of passenger cars as well as delivery trucks in traffic)
- roads and intersections with mixed traffic (mostly voivodeship and district roads characterized by the presence of trucks, trucks with trailers and passenger cars)

Table 2

Technical classes and categories of roads in Poland

Category of road	Class of road
National	Class A - motorways
	Class S - expressways
	Class GP - main roads of a higher standard
Voivodeship/regional	Class GP - main roads of a higher standard
	Class G - main roads
County/district	Class GP - main roads of a higher standard
	Class G - main roads
	Class Z - collector roads
Communal/municipal	Class GP - main roads of a higher standard
	Class G - main roads
	Class Z - collector roads
	Class L - local roads
	Class D - access roads

Source: [15]

It should be noted, however, that the functionality of an infrastructure element may also be assessed by analysing the structure of the network [16,17]. The identification of infrastructure objects in terms of their functionality is presented in [18].

3. RESEARCH METHODOLOGY AND CHARACTERISTICS

3.1. Methodology of the study

In order to determine the dependence between the function of the intersection in the transportation network and the influence of the countdown timers used at Polish signalized intersections on the traffic conditions, three research objects with different types of traffic were selected. The estimation of the investigated dependence consisted of traffic safety analyses at intersections with countdown timers that were switched on and off. Therefore, the impact of the timers on the number of passes over the stop line during the red signal was studied. The measurements were carried out in two measuring periods with the devices switched on and off. The studies were conducted for a total of 13 working days between the hours of 07:00 and 19:00 for all objects.

Within the study, the main recorded measures were:

- the moment of passing over the stop line by a driver travelling in a particular direction in a certain lane when the red signal was displayed
- the moment of passing over the stop line by a driver travelling in a particular direction in the certain lane when the yellow signal was displayed

At each intersection these moments were recorded for the approach where the traffic was moving towards the city centre.

For the purpose of identifying the intersection function at the same time as the basic research, additional measurements were also carried out for the following traffic characteristics:

- traffic volumes in 5-min intervals
- the structure of traffic with respect to the direction, along with the accuracy of the relation in the lane
- the structure of traffic based on the group of vehicles in 5-min intervals with the following categories of vehicle: passenger cars (so), delivery trucks (sd), microbuses (mi), trucks (sc), trucks with trailers (scp), buses (a), articulated buses (ap), minibuses (mi), motorcycles (m), bicycles (r), other (i)

The characteristics of traffic were recorded using a video camera and then analysed by the analysts trained for this purpose. During the measurements, special attention was paid to the placement of video cameras in order not to affect the behaviour of the vehicle drivers. The cameras were set so that they were not visible to vehicle drivers. Example photographs of the measurement sites are shown in Figure 3.

a) The measurement site – car with a located camera

b) The measurement site – the camera in the car

Fig. 3. The measurement sites

The research sample for all intersections totalled 233,392 pcu/312h. There were 116,696 pcu/156h in the period when the countdown timers were switched on and 118,004 pcu/156h in the period when the timers were switched off (i.e., 1,308 pcu/156h more).

3.2. Methodology of the study

In the first stage of the process of selecting the research objects, a group of intersections with countdown timers installed, as well as with differentiated traffic structures (and hence with different types of traffic), was chosen. This selection was based on a map for the analysis of road categories. The final selection of the objects for analysis (Stage 2) was determined by the measurements of traffic, which were performed together with the analysis of its structure.

Thus, three intersections were chosen and initially assigned their functional characteristics, as shown in Table 3.

Table 3

Measurement points (intersections)
with a preliminary assessment of their functionality

City	Names of crossing roads	Preliminary functional classification of the intersection
Zabrze	De Gaulle'a and Roosevelta	Urban
Opole	Obrońców Stalingradu, Mieszka I and Jagiellonów	Mixed
Wrocław	Aleja Karkonoska, Zwycięska and Jeździecka	Non-urban

The object in Zabrze was a four-approach intersection, with two lanes at each approach. At the intersection, a three-phase signal control is installed, which operates according to four programs with fixed cycle lengths. This object has no additionally separated right-turn lanes nor S-2 traffic signals, which display the signal for turning in the direction indicated by the arrow. The intersection is about 1 km from the Diametrical Road Route (the voivodeship road), which is one of the main connections between the cities in the Upper Silesian Agglomeration.

The object in Opole was also a four-approach intersection. Obrońców Stalingradu Street, which connects the city centre with Motorway A4, is Voivodeship Road no. 435, while Jagiellonów and Mieszko I Streets are district roads. The traffic is controlled by fixed time three-phase signalling. At the examined approach (Obrońców Stalingradu towards the city centre), an additional traffic signal S-2 is installed, but only in the lane for turning right.

The object located in Wrocław was the largest of those selected for measurements. It is a four-approach intersection with 12 lanes in total. There are three lanes at the approach in which passes over the stop line during a red signal were examined. Signalling at the intersection is based on four programs, which work according to fixed schedules. The crossing streets are of district and commune categories. The intersection is part of National Road no. 5 (E261), which connects with Motorway A4 (located approximately 2 km from the highway).

4. DETERMINING THE FUNCTION OF THE INTERSECTION ON THE BASIS OF OWN RESEARCH

To determine the function of the intersection in the transportation network of the city, the structure of traffic in terms of vehicle group at all examined approaches of each of the intersections was analysed. Figures 4 to 6 show the structure of vehicle groups throughout the entire measurement period, split into 5-min time intervals. The vehicles identified during the study were aggregated into five groups: car (C), delivery truck (DT), minibus (Mi), truck (T), bus (B), motor and bike (MB).

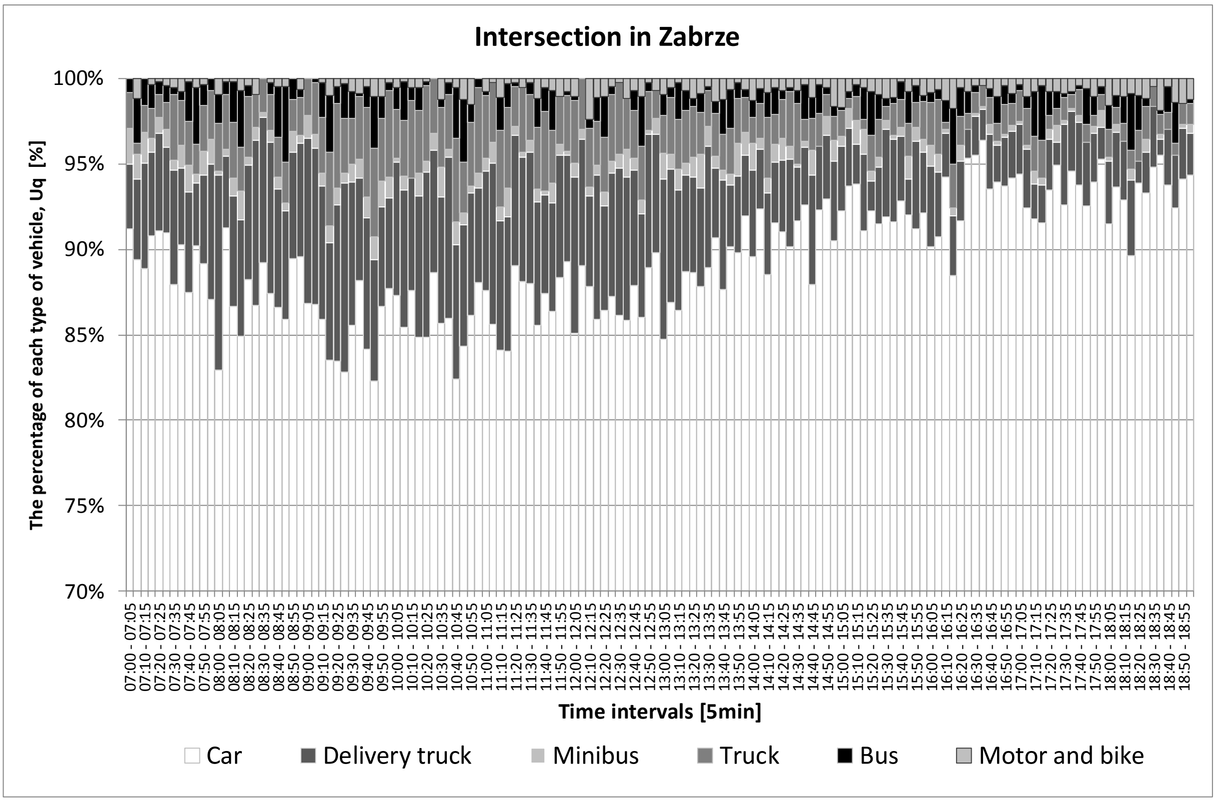


Fig. 4. The structure of vehicle groups at the intersection in Zabrze

Figure 4 shows the distribution of the structure of vehicle groups at the intersection in Zabrze. The minimum share of passenger cars in a single measurement interval (5 min) was 82% and the maximum rate was 96%.

Figure 5 shows the distribution of the structure of vehicles at the intersection in Opole. The minimum share of passenger cars in a single measurement interval was 78%, while the maximum rate was 90%.

Figure 6 shows the distribution of the structure of vehicle groups recorded at the intersection in Wrocław during measurements. The minimum share of passenger cars in a single interval was 74%, while the maximum rate was 92%.

The average shares of the particular groups of vehicles for the entire analysed period are presented in Table 4.

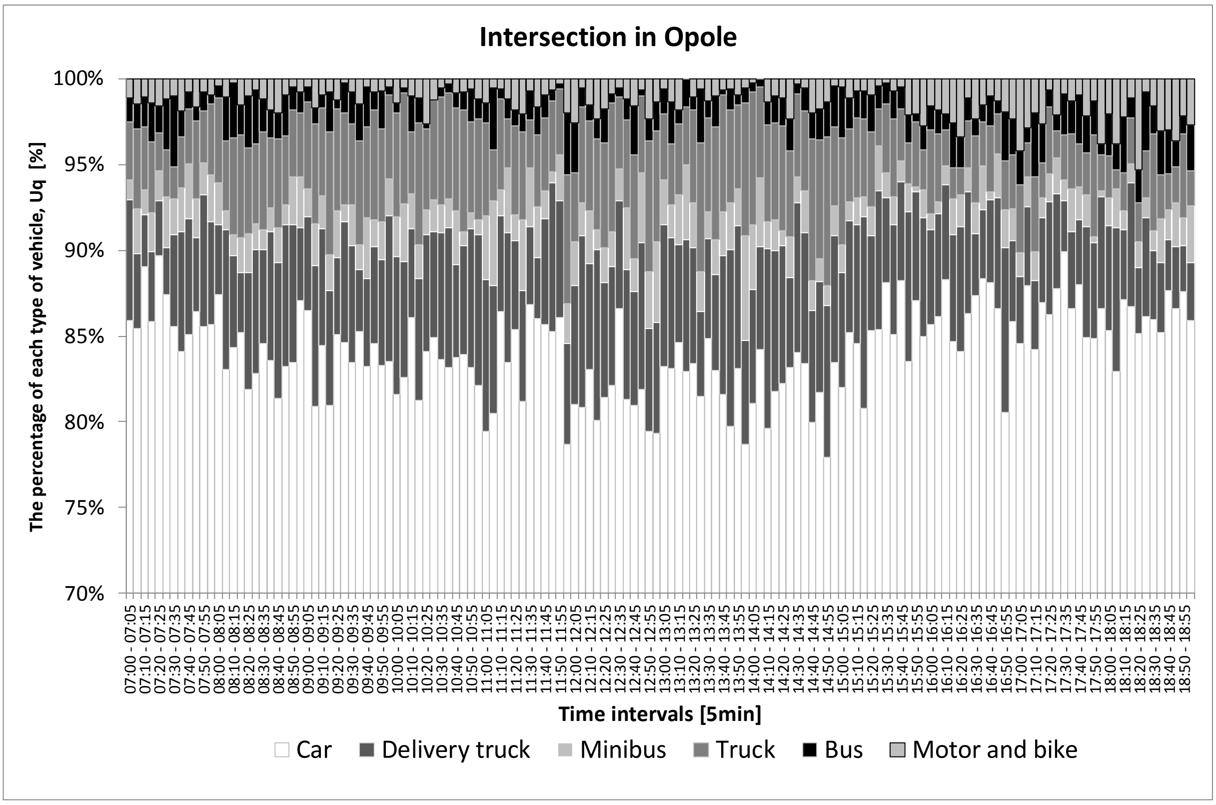


Fig. 5. The structure of vehicle groups at the intersection in Opole

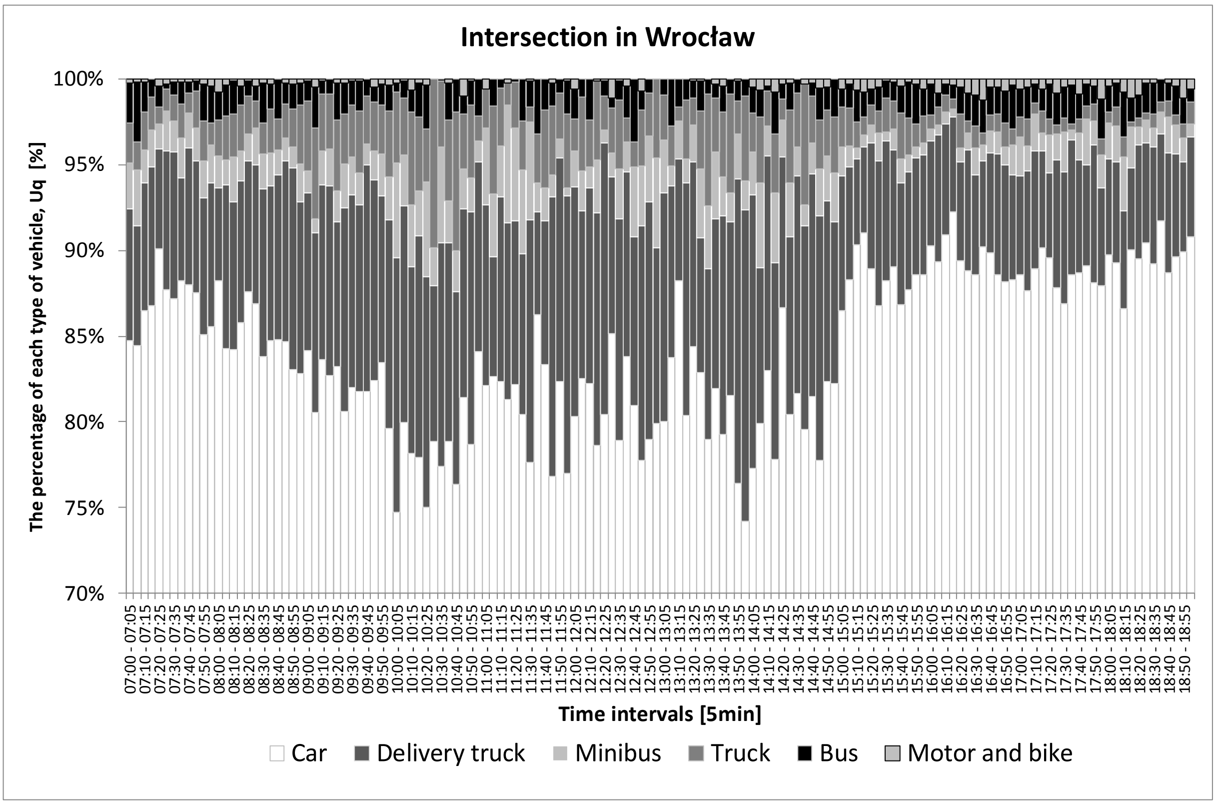


Fig. 6. The structure of vehicle groups at the intersection in Wrocław

Table 4

Average share of each group of vehicles in [%]
for the entire analysed period

City	Car	Delivery truck	Minibus	Truck	Bus	Motor and bike
Zabrze	89.73	5.28	0.77	2.37	1.15	0.70
Opole	84.25	6.33	2.04	4.51	1.57	1.30
Wrocław	84.48	9.23	2.11	2.42	1.42	0.34

The largest average share of passenger cars and the lowest average share of delivery trucks and trucks among the analysed objects occurred at the intersection in Zabrze. In turn, the object in Wrocław was characterized by the largest share of delivery trucks and trucks, i.e., 11.65%. At the intersection in Opole, the share of passenger cars was smaller than at the junction in Zabrze and similar to the intersection in Wrocław. A smaller share of trucks was also observed, compared to the intersection in Zabrze, as well as a smaller share of delivery trucks and other trucks compared to the examined object in Wrocław.

5. CONCLUSIONS

The aim of the article was to present the research methodology applied in order to perform measurements for determining the influence of the use of countdown timers on the level of traffic safety, depending on the function of the road intersection in the transportation network. The methodology involved undertaking basic research, which relied on the identification of the number of passes over the stop line during the red signal, alongside additional studies, with the aim of determining the function of the intersection based on the measurements of the traffic volumes and the structure in terms of vehicle groups.

Before beginning the basic research, the examined objects with countdown timers were selected and a preliminary functional division of the intersections in terms of the type of traffic (urban, mixed or non-urban) was made.

The results of the studies on traffic volume and the structure of vehicle types validate the assumed preliminary functional division of the examined intersections. For example, at the intersection in Zabrze (mainly with urban traffic), the passenger car share was dominant (over 89%), which was the largest rate in comparison with other objects. At this intersection, the share of delivery trucks and trucks was smaller than at the other intersections. The largest share of these types of vehicles has been observed at the intersection in Wrocław, i.e., at the one that was preliminary assumed as the intersection with non-urban traffic. At the intersection in Opole, the share of passenger cars was smaller than at the intersection in Zabrze and similar to the values for the intersection in Wrocław, while the share of delivery trucks and other trucks was larger than at the intersection in Zabrze and smaller than at the intersection in Wrocław. These results confirm the correctness of the initially assumed functional division of the intersections investigated by the study.

During further research, some new solutions for drivers should be considered. First of all, visual information is critical in order to better understand transport system solutions [19]. It is also vital to explore smarter planning on a global scale [20] and the relation between drivers and autonomous vehicles [21].

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