ANALYSIS OF SELECTED METHODOLOGICAL PROBLEMS REGARDING THE EXAMINATION OF TRAFFIC EVENTS AT ROAD INTERSECTIONS

ANDRZEJ METELSKI[1]
Opole University of Technology

Summary

The planning of statistical examining of population within the scope of undesirable events at road intersections with three-colour traffic lights has been discussed. In particular, the problems have been raised that are related to the analysing how the installation of countdown timers showing the time left to a change in the traffic lights signal affects the traffic flow. Attention has been focused on selected research process elements that concern the preliminary works, examination proper, and statistical inference, without describing the types and engineering designs of the displays used and without dealing with the legal aspects. Selected literature items related to the subject matter touched upon have been analysed, with pointing out the practices that either might be desirable or might arouse some reservations. In the part concerning the preliminary works, such issues as the sample selection method, sample size, and selection of the variables under analysis have been discussed. As regards the examination proper, some elements of the information acquisition process have been considered in both the subject-related and object-related aspects. When discussing the statistical inference, some limitations have been pointed out that affect the conclusions drawn from the examination of statistically non-representative samples and some acceptable methods of the analysis of empirical data have been mentioned. The article has been concluded with a brief recapitulation.

Keywords: methodology, countdown timers, preliminary works, examination proper, statistics.

1. Introduction

Road traffic participants are forced to make complex choices when crossing road intersections with traffic lights. When the light signal is changing from green to red, the motor vehicle driver must make a decision whether to apply brakes with higher or lower intensity or to cross the intersection. It happens quite often that he/she enters the intersection after the red signal is turned on. An incorrect decision may result in a collision with other traffic participants or the payment of a fine. In many countries, attempts are made to reduce the occurrence of such events by providing forewarning information in the form of e.g. flashing green lights such as those discussed in [7] or countdown timers [2, 23].

[1] Opole University of Technology, Faculty of Production Engineering and Logistics, ul. Sosnkowskiego 31, 45-272 Opole, Poland, e mail: a.metelski@po.opole.pl

The influence of forewarning information on the reduction of risks and on the change in traffic flow capacity of intersections was already the subject of numerous research works and the results obtained often led to contradictory conclusions [2, 8, 20, 23]. No wonder, therefore, that the systems of this kind cause so many controversies and have at least as many supporters as opponents. Generally, the supporters of countdown timers put forward arguments concerning the streamlining of intersection crossing [23]. There are also studies according to which the countdown timers cause a drop in the number of infringements of road traffic regulations, including the number of cases of entering an intersection at the red or amber light [12, 18, 21, 22]. On the other hand, the opponents highlight the experiments showing that the installation of countdown timers results in an increase in the speed of the vehicles crossing the intersection, even to exceed the speed limit. They also suggest that the "dilemma zone" is thus extended and an increase takes place in the number of cases of entering an intersection at the red or amber light [14, 17, 23, 24].

One of the reasons for the above contradictions is undoubtedly the fact that the observations were carried out at various locations and it is well known that individual countries or even individual towns in the same country differ from each other in the local road traffic conditions and vehicle driving styles. Although the discrepancies observed may be explained by the factors mentioned above, some of the research results available arouse some reservations about the methodology adopted. Even the problem as such seems to be insufficiently explored and requires further more in-depth research. Therefore, this study has been undertaken, where selected limitations and rules governing the examination of traffic events at road intersections have been dealt with. Examples of the practices that may either be considered correct or arouse some doubts have been indicated.

2. Preliminary works

The problems of planning the statistical examining of population within the scope of undesirable events at road intersections is an important subject because ill-considered experiments give results whose usability for the formulation of valuable conclusions seems to be doubtful. All the experiments should be carefully designed and this is started from a stage referred to as "preliminary works", which includes:

- defining of the population under examination;
- preparation of a list of the population under examination;
- defining of the subject and object of the examination;
- formulation of the problems to be solved and the hypotheses to be verified;
- defining of the sample size;
- choosing of the sample selection method;
- preparation of a list of the variables to be examined.

To explore the impact of countdown timers on the traffic safety and flow capacity, the use of two groups of methods may be generally considered. The first one is related to examining the population of road intersections. In such a case, the object to be examined

is an intersection and the subject of examination may be e.g. the traffic flow capacity of the intersection or the number of traffic events during a specific period [5]. The other one is applicable to the experiments related to the population of vehicle drivers or pedestrians. In this case, the subject of the analyses may be the reactions of traffic participants to the forewarning information provided by traffic lights [3]. Various hypotheses may be formulated for the objects and subjects of the research, e.g. the one predicting that the installation of countdown timers will streamline the crossing of an intersection with traffic lights. It is also possible to formulate various tasks to be performed, to analyse various relationships, to build new mathematical models, to select the shape and parameters of an approximating function, to verify general regression models, etc.

Individual hypotheses and tasks are analysed with using variables, i.e. the characteristics in which individual elements of the population under consideration differ from each other. The list of the variables to be examined should be thoroughly thought out. It is advisable to verify such a list by means of pilot tests or, at least, literature studies. The variables observed that are related to the issue under consideration include e.g. vehicle speed [4, 14, 15, 16, 17], maximum acceleration and braking deceleration [3, 4, 19], driver reaction time [3], distance to the stop bar [15], entering the intersection during the red or amber indication [3, 6, 12, 16, 17, 21, 23], number of undesirable traffic events at the intersection [5], distance between vehicles [21], traffic intensity [23], vehicle type [4, 19], etc. It would also be wise to introduce the variables that would enable analysing the sample structure as regards selected aspects, such as driver's sex or vehicle type. In the case of statistically non-representative samples, this would provide a possibility of preliminary assessment of the quality of the data collected.

Samples may be divided into two groups:

- statistically representative;
- statistically non-representative.

In general, a sample representative for a specific population in respect of the variable examined is defined as the one that, for the variable examined, yields the population parameter estimates falling within the required accuracy limits around the corresponding population values. The procedure by means of which the sample has been drawn produces such representative samples with a probability defined by the confidence coefficient adopted [13]. The notion of a "representative sample" is related to: absence of the selectivity of the choice of units; miniaturization of the population; selection of typical cases; selection method enabling accurate estimation of population parameters [9, 10, 11].

The statistically representative samples provide grounds for generalization onto the entire general population and they are drawn in accordance with predefined rules. The selection of such a sample should meet the requirement of probabilistic randomness. Such a criterion is met by:

- simple random sampling;
- systematic random sampling;
- stratified random sampling.

If the randomness requirement is not met, the sample should be considered as statistically non-representative. For such samples, any inference concerning the general population would be groundless; only presumptions about some trends might be formulated. Such samples do not have to be selected as rigorously as it is in the case of representative ones and, in general, the sample size does not have to be very large. The randomness does not take place in the case of:

- convenience (haphazard, accidental) sampling;
- purposive (judgmental) sampling;
- consecutive (total enumerative) sampling;
- snowball sampling.

The acquisition of information about traffic participants at road intersections in real conditions is convenience rather than random sampling. Therefore, the statistical representativeness cannot be talked about in this case. Nevertheless, the sampling method should meet the requirements for using observation as a research method. The observations should be purposive and comprehensive. The information obtained should be collected and interpreted as events or phenomena having an impact on the elements and processes of a specific system or structure. It is indispensable to take into consideration all the stages of research activities, to verify and sort the material collected, and to help formulate hypotheses. The observation as a research method differs from simple noticing in that it is a continuous and purposive process. It should be carried out according to a plan so that it should not affect the subject of the research. This means that it must be objective, i.e. effectively counteract subjective limitations [1].

As mentioned previously, the research on countdown timers often led to contradictory conclusions. As an example, both beneficial and detrimental effect on the traffic flow capacity of intersections or on an increase or decrease in the number of infringements of road traffic regulations was recorded. This may be acceptable when different populations are explored, but the drawing of contradictory conclusions for the same population may result e.g. from either strong bias of the sample drawn (impossible for accurate determining in the case of statistically non-representative samples) or failure to take into account the factors that have a significant impact on the subject of the research.

Theoretically, the random selection of sample elements may be used at the examination of drivers' behaviours in laboratory conditions. Thanks to the random selection, the conclusions might be generalized either onto the general population or onto its individual stratum, depending on the sample type. In practice, however, the random selection does not occur. In most cases, the experiment participants are either volunteers recruited from academic circles related to the author of a publication, as it was in [3], or people found by public advertisements. The candidates are recruited from the people that meet predefined criteria, such as e.g. appropriate driver's experience, minimum annual mileage travelled as a vehicle driver, absence of specific physical and psychical dysfunctions, number of motor vehicle accidents in which the candidate took part, or number of recorded infringements of road traffic regulations. Obviously, a sample thus selected does not fully represent the general population.

Apart from the representativeness problem, another interesting issue is the sample size. For randomly selected samples, the procedure is obvious and many formulas exist that would make it possible to determine the minimum sample size for the inference to be kept at the significance level required. There is also a variety of appropriate computer software generally available, including sample size calculators, which can be found in the Internet. In the case of non-random samples, the sample size is determined by the expert involved, based on historical data or his/her own judgements. The sample size may also be determined by the minimum sizes required at specific data analysis techniques, e.g. based on the expected minuteness of detail of the cross-classification. In a definite majority of publications, no information is provided why a specific sample size has been chosen. Unfortunately, it also happens that the selection of a sample size in a statistically non-representative case seems to be more closely connected with technical or economic limitations than with considerations related to inference needs.

3. Examination proper

Following the preliminary works, the examination proper is started, i.e. a sample is drawn so that the data collected are sufficiently reliable. The research material should be complete and honest, i.e. the subject-related and object-related requirements for the research must be met. The subject-related requirements are considered as met when the actual situation is recorded completely, impartially, and based on thorough knowledge of the subject of the research. The object-related requirements are based on appropriate selection of research methods, techniques, and tools. The process of information acquisition at road intersections includes, inter alia, the defining of:

- measuring points;
- measurement time;
- measuring method;
- number of observers and quantities measured by each of them;
- measuring techniques;
- measuring and recording equipment.

In particular, the selection of a few measuring points, making it possible to compare measurement results and to compile consolidated measurement results, should cover road intersections with similar technical characteristics and similar traffic type and intensity. As regards the measurement time, it is recommended to make a distinction between various types of measurement periods (morning rush hours, afternoon rush hours, or off-peak period). When such variables as traffic intensity are analysed, the measurement should not be carried out on the days when the traffic differs from the normal one (e.g. when mass events are organized nearby or on official holidays). Moreover, if measurements are to be repeated several times, they should be carried out at the same measuring points and in similar weather conditions.

In the literature, both correct practices and practices arousing some reservations are reported. A few examples have been given below. An example of the latter group is the

research done by Zarząd Dróg Miejskich (Municipal Road Administration) in Grudziądz in cooperation with Klub Inżynierii Ruchu (Road Traffic Engineering Club) to explore the effects of operation of the countdown timers displaying the time left to the end of the green indication [17]. The observations were carried out at a selected intersection in Grudziądz from 1 March 2014 to 31 July 2014. The parameters recorded were traffic intensity and speeds of the vehicles that moved in the two road lanes where straightforward drive was possible. As the reference period, January and February 2014 were wrongly chosen, when the countdown timer did not function. One of the parameters taken for comparisons was the number of vehicles that entered the intersection with speeds exceeding 61 km/h and this number recorded in winter, without the timer, was compared with the corresponding figure recorded in summer, when the timer was active. Apart from that, the measurements were carried out continuously, i.e. in very different weather conditions. What is more, only the data measured for the right lane were available during the period from May to 18 July, because of a failure of one of the data recorders. Additionally, it was mentioned in the report that a photo-radar visible for vehicle drivers was installed in the traffic lane under examination, which undoubtedly had an impact on drivers' behaviours and, in consequence, on the final examination results. The data collected did not provide grounds for determining the bias in the examination results, caused by the presence of the photo-radar, and for indicating any reliable trends for the general population. Furthermore, a considerable part of the information provided in the report does not make any sense from the statistics point of view. As an example, the highest vehicle speed value recorded in a specific month may only serve entertainment rather than scientific purposes.

Sometimes studies may be found in the literature where data are summarized in the form as shown in Table 1 [23]. Obviously, differences between individual values may be caused by reasons other than the functioning of time displays. Therefore, the datasets of this type are of almost no value for the studying of the impact of countdown timers on the system of safety of road traffic participants.

Table 1. Traffic events at the intersection of Armii Krajowej Street and Piastowska Street in Cracow (data for 2012 and 2014 with no time displays; data for 2013 with time displays). Source: Zarząd Infrastruktury Komunalnej i Transportu (Municipal Infrastructure and Transport Administration) in Cracow

Year	Accidents and collisions			Victims			Events related to non-compliance with traffic lights
	Total	Accidents	Collisions with pedestrians	Lightly wounded	Seriously wounded	Killed	
2012	15	1	1	1	0	0	5
2013	12	3	0	2	2	0	7
2014	15	2	1	2	1	0	8

The impact of countdown timers on the system of safety of road traffic participants was also examined at four street intersections in Toruń and the results of that examination have been presented in a similar way in article [5]. In that study, the numbers of traffic

events recorded at those crossroads for a period of four years have been compared with each other; for the first two years, the countdown timers did not function. The total numbers of the traffic events that occurred during these two periods were close to each other. There were intersections where the number of traffic events increased; there were also intersections where a drop in this number was recorded. In consequence, neither positive nor negative impact of the time displays on the system of safety of road traffic participants could be confirmed.

The impact of time displays on the number and time of the cases of entering an intersection at the red or amber light was also examined at three selected intersections in Zabrze, Opole, and Wrocław in April and May 2015 [23]. In Wrocław, the time of the periods under analysis totalled 72 hours and it totalled 120 hours in Opole and Zabrze each. The measurements were carried out continuously from 7:00 a.m. to 7:00 p.m., without taking into account variations in weather conditions. The road intersections selected were situated in towns of different size; they also considerably differed from each other in their technical characteristics. Therefore, the reasonability of the presentation of overall analyses in this case is a debatable issue. On the other hand, it would be valuable to extend the scope of this research to measurements carried out during night hours or in other seasons, especially in winter conditions.

The above shows only a few examples of methodological shortcomings or too narrow a spectrum of the research. There are also many reports that describe the research on the impact of countdown timers, carried out with particular attention being focused on the avoiding of changes in the factors that might affect the subject of the research. As an example: in the work reported in [6], data were only collected during sunny weather. In [4], it was made sure that the six intersections selected were characterized by similar technical specifications and similar traffic intensity. In [15], intersections of the main arterial roads in the central part of the town, with a minimum impact of pedestrian and bicycle traffic and with similar technical characteristics, were selected. In [19], the traffic flow capacity was only examined during the off-peak hours (when vehicles were not stuck in traffic jams). An interesting work has been described in [16]. In that paper, a long-term analysis of the impact of countdown devices on drivers' decisions to stop or go at a change to the red light has been presented (the measurements were carried out before the installation of the countdown timers and one and a half months, four and a half months, and seven and a half months after the installation).

The examination proper may be supplemented with follow-up measurements to confirm the correctness of the research work carried out. The follow-up measurements should be performed on another sample of the population under analysis, based on the same techniques, methods, and tools as used at the main measurements.

4. Processing of the statistical data

After the examination proper, the material collected should be arranged in separate data groups, processed, and presented in a graphical form. The data quality should be preliminarily verified, e.g. by checking whether the sample structure is consistent with the

structure of the population under examination in respect of certain distinguishing features (if predefined at the experiment planning stage). A frequent and necessary practice is the rejection of outliers, which arise from measurement errors or refer to individuals significantly differing from standard [3]. The empirical data are presented in the form of tables [6, 16, 19, 21], bar graphs and histograms of the number (frequency) of occurrences [19, 23], and scatter diagrams [4, 6, 15].

Following the processing of the raw data, the inference is started. The convenience sampling precludes any accurate generalization onto the general population. For statistically non-representative samples, it is possible to analyse the empirical series of data and to indicate the presumable trends in the general population. Typically, the descriptive statistics is used [4, 6, 12, 15, 21] and the distribution of the feature under consideration is presented with using frequency graphs or empirical cumulative distribution functions [4, 7, 15, 24]. Tests of goodness-of-fit of empirical and selected theoretical distributions are quoted [4]. To analyse the impact of the inter-group factors on the dependent variable, the analysis of variance is used [3]. Classic parametric tests are also used, such as e.g. the Student's t-test to compare the mean values for two samples [6, 12, 21], or a comparative test of structure indicators [16]. In certain more interesting studies, attempts to adjust selected models to empirical data are additionally reported [4, 15, 19, 24]. The studies are usually concluded by formulating next problems to be solved, which arose during the research process.

5. Recapitulation

This study does not show all the problems related to the methodology of the research on behaviours and events at road intersections; it only signals selected problems related to this subject matter. The approval of countdown timers for general use should be preceded by thorough research works on the technical and legal aspects of this issue. Unfortunately, the available results of analyses of the impact of such devices on the system of safety of road traffic participants or on the traffic flow capacity of intersections are insufficient. It seems very recommendable to carry out further more in-depth research that would make it possible to draw true conclusions on the trends in the general population. Without the said research, the making of any inferences on the need of changes in the safety system or in the regulations in force is inappropriate. The multiannual functioning of road intersections provided with countdown timers makes it possible to analyse the impact of the timers on the system of safety of road traffic participants and on other factors, on condition that in-depth and reliable research on this issue is carried out.

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