DRIVER'S PERCEPTION AND REACTION TIME AS AN IMPORTANT ISSUE FOR URBAN TRAFFIC MODELLING

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Abstract

The driver behaviours are one of the crucial determinant for the transportation system functioning, especially within the city. They are shaped mainly by driver's individual perception of reality. Many examples from literature shows, that the perception is strongly associated with a human perception. The process of analysis and understanding of factors affecting driver perception can help with planning more effective and safer transportation facilities, i.e. road infrastructure. The driver reaction time is a parameter which describes a perception and directly affects the road safety. Thus the ability and required accuracy of its measurement is an important element in traffic modeling. In this work the results of microscopic traffic simulation for selected Cracow artery have been presented, considering the fluctuations of the mentioned above parameter . The aim of the studies was to analyze the impact of driver's reaction time parameter changes on traffic simulation effectiveness. As a result, the importance of potential measurement error of driver reaction time has been presented. Furthermore the effects of conducted research shows the significance level of impact reaction parameter measurement error on the urban traffic simulation model, which is very often a basis for future planning of transportation system elements. The calculations have been performed for selected traffic parameters in the context of statistic compatibility of the model by the use of Aimsun software.

Keywords: Driver's reaction time, perception, measurement accuracy of driver reaction, traffic micro simulation

1. INTRODUCTION

The driver's reaction for any traffic incident or object on a road requires some time for recognition, understanding the situation, decision making about reaction and finally reaction taking. Put simply, the perception-reaction process involves *detection, identification, decision*, and *reaction.* These four terms are defined as follows:

- *Detection* of information, based on visibility, which is the visual awareness that an object is present on the roadway. At night, it depends entirely on a contrast sensitivity;
- *Identification* is the process of gathering information about the object until enough information is gathered for the driver to make an appropriate decision of the object recognition, whether it cause a danger, and whether its existence calls for some responsive action;
- *Decision*, or evaluation, is the next step and it involves the driver's decision about taking appropriate action to avoid the object
- *Reaction* occurs then orders are issued by the driver's brain to the appropriate muscle groups in order to initiate the responsive action for traffic incident [9].

Analysis of road safety takes into account a number of factors that affects the way of driver's movement in the selected area or point of the road. These factors are part of the road traffic system, which consists of four main elements: human, other road users, vehicles and roads, traffic and its organization (**Figure 1**). The correct interaction of these elements provides an effective and safe realization of movement by the traveler.

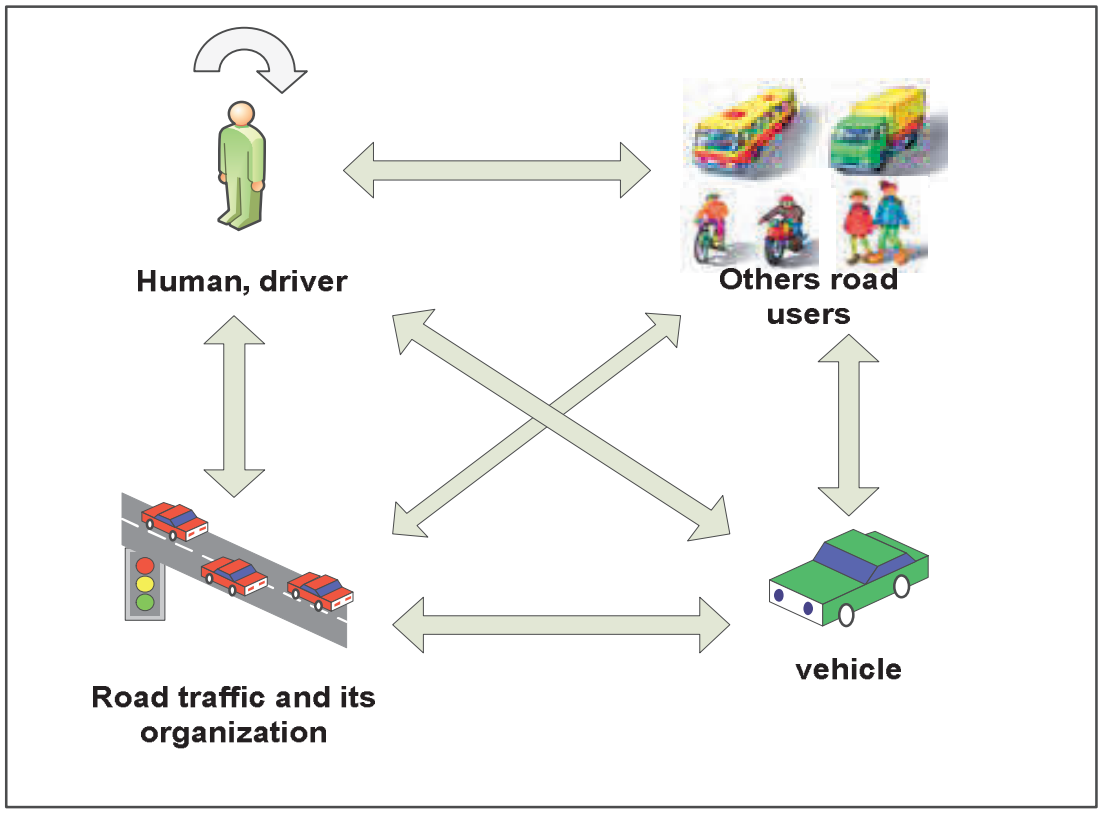

Figure 1 Traffic system

To the technical category in the road traffic system, the road, traffic and its organization as well as vehicles can be attributed. A road in directly and indirectly manner affects the formation of a number of road accidents. Such features of the road network, like lack of hierarchy and the associated with it availability control, as well as a limited range of different types of movement segregation create the conditions for dangerous behavior of traffic participants [2]. To the non technical category a driver and other road users can be included.

Participation in the road traffic system is a set of complex actions and driver's behavior as a result of forming relations with other elements of the system. Dexterity in the handling of the vehicle combines three areas:

- physical state determined in medical card,
- mental state determined in psycho-physical medical card,
- knowledge, skills and attitude of the driver [4]

Dexterity in the handling of the vehicle by the road user directly affects its behavior in road traffic. The results of this kind of behavior are many adverse effects on the environment, where the most important include traffic accidents, collisions, formation of traffic congestion and excessive pollution. Driving behavior often depends on driver's perception on the way, which is how he perceives, interprets and reacts to events resulting from driving. Thus, the rate of driver reaction is the result of his time reaction to the situation occurred.

2. THE PERCEPTION OF THE ROAD TRANSPORT SYSTEM

There are many definitions of perception, in spite of this, it can be noticed that they are all consistent with each other. Universal Polish dictionary defines perception as a cognitive process based on perception, unawareness of objects, phenomena and processes occurring as a result of certain stimuli to the senses [16]. According to dictionary of foreign words perception, i.e., observation is a conscious sensory response on the external stimulus; a method of reaction of obtaining impressions [8].

It should be noted that perception is not only in the reception or registration of certain sensations and their processing through the senses in accordance with the way of thinking of each person. This means that for the same impressions, it is possible to make different conclusions and different ways to interpret them. The person processes the information received, mainly on the basis of the previously accumulated experience in the same or similar situations, schemes or behaviors. What and how people perceive (especially in ambiguous situations), also depends on their knowledge, current emotional state, attitudes, opinions and beliefs [13].

In scientific literature there is a notion of reaction time (Perception-Response Time), which is defined as the period of time that begins with the emergence of the phenomenon or appearance of an object in driver's field of vision and ends when he respond to it (brakes or turn the steering wheel) [7]. In this regard, several studies aimed at the identification and determination of influence of external environment on the behavior of the driver in the road transport system has been performed. This kind of research is conducted to improve the safety of the driver and other road users.

Żakowska [18] indicates the concept of perception of security, which relates to safety behavior during displacement of the driver in traffic. She speaks about the issues related to objective and subjective feeling of the driver to the road on which he moves.

Due to the fact that the perception refers to receiving a certain stimuli from the environment and response to it, in transportation engineering a numerous studies from that area have been carried out. Usually they address the problem of driver response to a traffic accident. Therefore, it can be assumed that the concept of "the perception of the driver" would be appropriate term that describes the behavior of the driver on the road and his reaction due to the occurrence of unexpected events.

Researchers have conducted a various studies on perception and reaction time of drivers. Its different for peoples in different age. The perception and reaction time for young drivers (18 - 30 years) is 1.65 sec and 1.95 sec for old drivers (56+ years) [15].

According to a NHTSA Technical Report, the perception and reaction time of drivers to apply the brake is 1.52 sec, based on the 95th percentile of drivers' brake reaction time [11]. The mean perception and reaction time as 1.5 sec Lerner studied out of 116 observations where drivers applied the brake in response to a surprise rolling of a trash barrel on a chain into the road [9]. The perception and reaction time was carried out from experiments using simulator. The time of 1.35 sec for pressing the brake pedal in response to the brake light was achieved [17].

3. DRIVER'S REACTION TIME

The driver's reaction time is a parameter, directly affecting the safety of road traffic. This parameter can be defined as the period of time counted from the moment the event occurs until the driver measures aimed at avoiding the adverse consequences of its occurrence. In scientific literature it can be find lots of methods to study the reaction time of drivers. In particular, it was determined through the method to a simple stimulus [6], by direct observation of traffic [12] or using a special equipment such as driving simulator [5]. However, regardless of the chosen method, each of them is characterized by its measurement error. The value of this error can significantly affect both further analysis and conclusions.

One of the examples that can change the drivers reaction time may be microscopic traffic simulation. The current world trend in the traffic simulation indicates very high popularity of this kind of methods. Analysis of microscopic simulation is performed mainly to verify and assess the possible transport solutions. The basic idea of a microscopic model is statistical consistent re-creation of real traffic. It is necessary to study a lot of characteristic factors of the simulated object. It may be the intensity of traffic flows, the generic structure of vehicles, response time, the representative path in a road network, traffic lights, etc. Thus, data quality can have a key value on results and duration of the calibration process of the model. The work investigated how

changing the reaction time affects the individual micro-simulation model parameters. This change can be equated with the so-called systematic measurement error, which is often trivialized due to the feature of repeatability in each of the studies. In the end, the results obtained always have a linear offset.

4. SIMULATION RESULTS - CASE STUDY OF CRACOW

To perform the analysis of these considerations, the program Aimsun 8 was used. It contain a functionality, which allow to simulate traffic on three levels of detail modeling: micro-, meso - and macroscopic. The one of the basic information in microscopic traffic simulation which has a significant impact on the progress and result of simulation are the parameters describing the drivers behavior. In the current version of Aimsun, there are three main types of parameters related with driver time response [1]:

1. Reaction time in traffic - is the response time, what is needed for the driver to adjust their speed to the preceding vehicle,
2. Reaction time at a standstill - the reaction time at the start of the preceding vehicle, which a driver need to start acceleration from a standstill,
3. Reaction time to traffic lights - is the reaction time to green light appearance at the intersection, when a driver is about to start moving.

In the conducted research a micro-simulation model for one of the main arteries of Krakow, the (so-called Trzech Wieszczy Avenue) was created. The actual values of these reaction times were determined based on the work of Ostrowski [12] and own researches of authors. These values served as the nominal variant, which has been changed in the range from -0.5 to +1.0 seconds in increments of 0.25. In addition, for the validation purposes of the model, a real traffic measurement from the 30 selected points of the road network have been applied. In this research the 8 traffic parameters and 1 statistical compatibility parameter were selected. These parameters are [1]:

- GEH statistic: is statistic test used in traffic engineering and traffic modelling to compare two sets of traffic volumes: real and simulated. If GEH statistic is less than 5 for over 85% of volumes in traffic models, the model has the statistical compatibility with real traffic. If GEH statistic is in range of 5 to 10, the traffic volumes should be investigated.
- Flow: average number of vehicles per hour that have passed through the network during the simulation period. The vehicles are counted when leaving the network via an exit section
- Travel Time: average time a vehicle needs to travel one kilometer inside the network. This is the mean of the entire single travel times (exit time - entrance time) for every vehicle that has crossed the network, converted into time per kilometer.
- Delay Time: average delay time per vehicle per kilometer. This is the difference between the expected travel time (the time it would take to traverse the system under ideal conditions) and the travel time. It is calculated as the average of all vehicles and then converted into time per kilometer.
- Stop Time: average time at standstill per vehicle per kilometer.
- Number of Stops: average number of stops per vehicle per kilometer.
- Mean Queue: average length of the queue in that section, expressed as the number of vehicles per lane. It is calculated as a time average.
- Vehicles Waiting to Enter - Number of vehicles waiting to enter the network
- Speed - average speed of vehicles per kilometers per hour.

The results of the tests are shown in **Table 1**.

Table 1 The impact of driver's reaction time variability on traffic simulation effectiveness

	Added changes to nominal reaction time [s]						
Measured parameters	**-0.50**	**-0.25**	**0.00**	**+0.25**	**+0.50**	**+0.75**	**+1.00**
Delay Time [sec / km]	220.2	236.5	224.8	247.3	260.0	277.4	321.5
Flow [veh / h]	8 482.0	8 885.0	8 814.0	8 569.0	8 421.0	8 210.0	7 776.0
Mean Queue [veh]	764.9	684.5	724.2	785.3	814.3	886.2	934.9
Number of Stops [- / veh / km]	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Speed [km / h]	19.5	19.2	19.3	18.6	17.8	17.0	15.7
Stop Time [sec / km]	183.5	198.9	188.4	209.6	222.7	239.4	284.1
Travel Time [sec / km]	275.8	292.0	280.3	302.8	315.4	332.9	377.0
Vehicles Waiting to Enter [veh]	378.0	378.0	368.0	550.0	682.0	656.0	1065.0
GEH statistic	**Percentages of detectors below GEH value**						
GEH<5	76.67%	83.33%	86.67%	80.00%	80.00%	73.33%	56.67%
GEH<10	96.67%	96.67%	96.67%	96.67%	96.67%	96.67%	90.00%

The conducted analysis reveals some important facts which can be considered at three levels:

1) Traffic modelling at the micro level:
   a) the driver's reaction time is an important element for traffic modelling. Its accuracy of evaluation affect the simulation results making that the statistical compatibility may not be provided for the real network.
   b) underestimating the response time parameter does not change significantly simulated traffic parameters. however. such a model has low statistical compatibility.
   c) overestimation of the response time parameter significantly worsens the simulation results as well as the value of statistical compatibility parameter GEH.
   d) whereas that any tool dedicated to microscopic simulation is characterized by a number of input parameters. improper values of driver's reaction time can extend the calibration process model - a planner can wrongly attempt to modify other parameters of the model.
2) Measurement of driver's reaction times:
   a) the usage of measurement methods. in which it is possible to occur a systematic error (e.g. manual direct measurement). it may significantly affect the quality of further analysis.
3) Driving behaviour in the transport system:
   a) delayed psychomotor reaction of given driving population significantly worsens the capacity of the road network. e.g. 0.5 seconds greater driver's reaction time reduces the flow by 4.46% and increases the average queue of vehicles by 12.45%; and in turn. a longer reaction time of about 1 second worsens the flow by 11.78% and an average queue by 29.11%.
   b) the drivers population with a longer response time to external stimuli worsens traffic flow - in extreme cases. the number of stops increased by 50% and speed decreased by 18.76%.
   c) the driver behaviour can adversely affect the exhaust emissions from vehicles by increasing the number of stops and time of stops in the queue at the intersection (increase to 50.79%).

5. CONCLUSION

The users behaviour in the transportation system is a crucial factor in terms of the efficiency and capacity of the road network. Therefore. it seems be needed that the knowledge in this field should be extensive. reliable and multifaceted. The presented study takes an attempt to evaluate how significant is the influence of the

drivers reaction time on three aspects: traffic modelling at the micro level. measuring of drivers reaction time and traffic parameters determination for the different values of reaction parameter. The obtained results confirm the previously defined thesis and indicate the future direction of research. It may refer to the comparison of different measurement methods and associated with it measurement errors of other parameters. which describe the driver behaviour and perception in the urban transport system.

REFERENCES

[1] Aimsun 8 Dynamic Simulator User's Manual. TSS-Transport Simulation Systems 2014.

[2] BUDZYŃSKI M. MICHALSKI L. GACA S.: Bezpieczna infrastruktura drogowa - obecne wyzwania. I Polski Kongres Drogowy Lepsze drogi - lepsze życie: referaty. Warszawa 4-6 października 2006.

[3] CHODUR J. OSTROWSKI K. Charakterystyka strumienia ruchu w początkowym okresie sygnału zielonego na skrzyżowaniu z sygnalizacją. Transport Miejski i Regionalny. no 5. 2012. pp. 3-9.

[4] GONTARZ A.. CZERWIENKO D.. POGORZELSKI I.. JURECJI L. Bezpieczeństwo samochodów pożarniczych w czasie jazdy i na miejscu akcji. Centrum Naukowo-Badawcze Ochrony Przeciwpożarniczej im. J. Tuliszkowskiego. Państwowy Instytut Badawczy. Józefów 2012. pp. 46.

[5] JURECKI R.. JAŚKIEWICZ M.. GUZEK M.. LOZIA Z.. ZDANOWICZ P.. Driver's reaction time under emergency braking a car - Research in a driving simulator. Maintenance and Reliability. 14(4). 2012. pp. 295-301.

[6] JURECKI. R.; STAŃCZYK. T. The test methods and the reaction time of drivers. Maintenance and Reliability. no 3. 2011. pp. 84 - 91.

[7] KARKOWSKI W. International Encyclopedia of Ergonomics and Human Factors. Volume 1. Second Edition. CRC Taylor & Francis. London. New York 2006. pp. 682.

[8] KOPALIŃSKI W. Słownik wyrazów obcych i zwrotów obcojęzycznych z almanachem. Nowe wydanie. Muza SA. Warszawa 1999.

[9] LERNER. N. D. Brake perception-reaction times of older and younger drivers. Proceedings of the Human Factors and Ergonomics Society 37th Annual Meeting. San Diego: Human Factors and Ergonomics Society. 1993. pp. 206-210.

[10] LOUMIET J. R.. JUNGBAUER W. G. Train Accident Reconstruction and FELA and Railroad Ligitation. Fourth edition. Lawyers & Judges. 2005. pp. 188

[11] NHTSA. Fourth report to congress: effectiveness of occupant protection systems and their use. Washington. DC: NHTSA 1999.

[12] OSTROWSKI K. Analiza zachowań kierujących pojazdami w stanach nasycenia ruchem na wlotach skrzyżowań z sygnalizacją świetlną. Czasopismo Logistyka. no 3. 2011.

[13] Przemiany struktury przestrzennej miast w sferze funkcjonalnej i społecznej. ed. J. SŁODCZYK. Wydawnictwo Uniwersytetu Opolskiego. Opole 2004.

[14] ROBINSON H. Perception. Routledge. London and New York 2003. pp. 2.

[15] SUMMALA. H. and KOIVISTO. I. 1990. Unalerted drivers' brake reaction times: Older drivers compensate their slower reactions by driving more slowly. In T. Benjamin (Ed.). Driving behaviour in a social context. Paradigme. Caen. pp. 680-683.

[16] Uniwersalny słownik języka polskiego. tom 3 O-Q. ed. S. DUBISZ. Wydawnictwo Naukowe PWN. Warszawa 2003.

[17] Van Winsum. W.. & Brouwer. W. Time headway in car following and operational performance during unexpected braking: Perceptual and Motor Skills. 3(2). 1997. pp.1247 - 1257.

[18] ŻAKOWSKA L. The role of geometric road design parameters in driving speed negotiation and safety perception: objective and subjective measures in simulation study. Advances in Transportation Studies - An International Journal. ATS Vol. XVIII (2009). s.17-38. Ed. C. Benedetto. Roma. 2009.