Scientific Journal of Silesian University of Technology. Series Transport
Zeszyty Naukowe Politechniki Śląskiej. Seria Transport

Volume 98 **2018**

p-ISSN: 0209-3324

e-ISSN: 2450-1549

DOI: https://doi.org/10.20858/sjsutst.2018.98.17

Journal homepage: http://sjsutst.polsl.pl

Article citation information:
Wala, M., Nowakowski, P. A method and application to identify reasons for decreasing vehicles' driving speed in cities. *Scientific Journal of Silesian University of Technology. Series Transport*. 2018, **98**, 181-190. ISSN: 0209-3324. DOI: https://doi.org/10.20858/sjsutst.2018.98.17.

Mariusz WALA[1], Piotr NOWAKOWSKI[2]

A METHOD AND APPLICATION TO IDENTIFY REASONS FOR DECREASING VEHICLES' DRIVING SPEED IN CITIES

Summary. Vehicle onboard travel planning systems have been developed in recent years. Since the development of GPS-based devices equipped with digital mapping applications for many vehicles, route planning has become easier and more convenient for drivers. Although such systems are used by drivers, for delivery or courier companies, it is especially important to provide a high-quality service, which involves the timely delivery of goods. Traffic management authorities are also interested in acquiring data on road and traffic conditions to verify the effectiveness and smoothness of the flow of vehicles. This paper proposes a method for traffic data collection and an application for recording data of variable factors having impact on a vehicle speed in cities and agglomerations. Data acquisition and identification of factors having impact on reduction of vehicle speed in the cities has been presented for a case study of Gliwice. The results can be useful for traffic management authorities, municipal traffic, road planning departments and mobile apps designers.

Keywords: vehicle driving speed, mobile application, traffic factors

[1] PST Transgór S.A. Jankowicka 9 Street, 44-201 Rybnik, Poland. E-mail: mar88@op.pl.
[2] Faculty of Transport, Silesian University of Technology, Krasińskiego 8 Street, 40-019 Katowice, Poland. E-mail: piotr.nowakowski@polsl.pl.

1. INTRODUCTION

The recent development of information technologies and mobile applications has provided drivers with the ability to plan a route and receive updated traffic data while travelling. Major software development companies enable such systems to view current traffic conditions, give notice of congestion and estimate the origin-destination time [1,2], as well as update traffic conditions in real time. A driver also has the option to choose an alternative route when any traffic congestion occurs. Among the most popular systems are Google Maps, ViaMichelin, TomTom, MapaMap, Targeo and Yanosik. Some of these systems are equipped with the option to register certain events or accidents that are disrupting traffic. However, the range of events that can be notified is limited. Furthermore, the estimation of travel time is a very important issue for goods delivery companies. At the same time, municipal traffic planning authorities need to be able to clear view traffic flow in their respective municipalities.

Traffic flow is determined by many factors, the most important of which depends on vehicle flow and types of roads [3,4]. In city centres, route planning is a demanding task. In many cases, drivers encounter congestion or very slow traffic [5]. Therefore, any deliveries of goods or transport of people may be disrupted or take a long time. There is also the issue of increasing vehicles exhaust emissions, which are dangerous to human health and the environment [6,7]. In peak hours in many cities, agglomerations and conurbations, when congestion phenomena occur, the driving speed decreases and the arrival at destination points is delayed [8]. Although some predictions concerning travel time delays can be estimated, it is difficult to identify precisely the reasons why vehicle speed decreases in a city. In many cases, except for increased vehicles flow, there are additional factors that impact on decreasing the origin-destination time. The most important are traffic lights, entering a main road from a subordinated road, slowly moving vehicles, roadworks, pedestrian crossings and bus stops [9,10,11].

In this paper we propose a method and application for registering all events occurring when driving a vehicle. The application may be installed on any tablet or smartphone equipped with a GPS receiver. All events occurring during travel can be recorded and subsequently compared with other data sources (e.g., traffic cameras or sensors).

2. IDENTIFICATION OF THE FACTORS DETERMINING VEHICLE TRAVEL TIME

Although the data collected from different types of traffic sensors contain much information, it is not possible to evaluate some of the important parameters that fully depict the transport system in cities or traffic flow [12]. In many cases, an individual driver has to estimate the driving time between the nodes of the origin-destination points in an agglomeration [13,14]. This concerns participants in supply chains, emergency vehicles and other commercial driving. It is important to minimize travel time for a selected route.

Many factors determine travel time and traffic flow, including the type of road, the number of lanes and congestion level, but some important parameters can occur randomly: traffic lights, slow moving vehicles, buses, trams, pedestrian crossings, types of buildings close to the road (e.g., shops, hospitals, schools). Congestion mainly occurs in cities and usually has two peak periods: in the morning and in the afternoon/evening.

Many of these factors cannot be easily evaluated by loops, video detectors and other sensors [15]. Vehicle flow depends on the number of vehicles passing the cross-section of a road as a unit of time. The unit of measurement for vehicle flow is the number of vehicles per hour (vehicles/h), vehicles per quarter hour or per day (vehicles/day). Traffic flow is the simultaneous movement of a set of vehicles in a certain sequence [16]. To describe traffic flows, some basic parameters of traffic flow must be determined or calculated. The average speed of motor vehicles in free traffic and good weather conditions can be calculated from Formula (1) [17,18]:

$$V_{avg} = 81 * f - \Delta V \qquad [\text{km/h}] \qquad (1)$$

where **D***V* is the increase or decrease in the average speed of the vehicle, depending on the fixed speed limit (2):

$$\Delta V = 0.56 * (V_c - V_l) * f * f_e \qquad [\text{km/h}] \qquad (2)$$

The coefficient *f* depends on the type and neighbourhood of the road in terms of average speed and is calculated by Formula (3). V_c is the calculated speed and V_l depends on the assigned speed limit.

$$f = \prod_{i=1}^{9} f_i \qquad (3)$$

Tab. 1 presents a detailed description of the coefficients.

Tab. 1

Coefficients having influence on a vehicle's average speed

Coefficient	Type of influence on V_{avg}
f_1	Road's cross section and width of lanes
f_2	Neighbourhood of the road
f_3	Type and condition of road surface
f_4	Side obstacles and parked vehicles along the road
f_5	Location of the road in the city
f_6	Curvature of the road
f_7	Inclining of the road
f_8	Junctions with other roads
f_9	Visibility of the roads surface

We propose an additional coefficient f_e (4) as a product of the coefficient determined by various (including random) events occurring in road traffic in cities.

$$f_e = \prod_{j=1}^{m} f_j \qquad (4)$$

This can include any delays as a result of slowly moving vehicles, pedestrian crossings, bus/tram stops, roadworks etc., as well as variable weather conditions or illumination and visibility on the road [19]. A number of additional coefficients can be adjusted to the purpose of research and tests related to traffic in a city.

3. METHODOLOGY OF TESTS – DESCRIPTION OF THE DATA COLLECTION

The proposed method for identifying events that can decrease vehicle speed in cities is based on registering thee reason why a vehicle is decreasing its speed or even stopping. The principle of the method and data collection is shown in Figure 1.

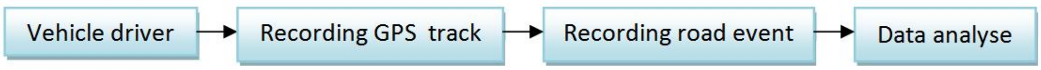


Fig. 1. Principle of data acquisition about events in the traffic

A device with an application must be equipped with a GPS receiver. A user/driver on a trip, while recording a GPS track, selects an appropriate icon when a road event occurs. A set of icons is configurable for characteristic conditions in a city. The set of icons can include signs for traffic lights, pedestrian crossings, bus stops, slow moving vehicles, bad weather conditions (ice, snow etc.) and many other phenomena to be defined by a user. Each encounter with an event in which a driver had to slow down or stop their vehicle should be recorded. The resulting data file includes the GPS track and events recorded by a driver or application user. An illustration of such a record is shown in Figure 2.

Fig. 2. Example of the speed profile of a route in a city including events that can impact on vehicle speed

It is therefore possible to determine the position and speed of the vehicle with satisfactory precision [20,21]. This kind of record accurately highlights the travel time delays for each section of a route. The results can be also sent dynamically to a traffic management centre [22,23].

The proposed method of data recording requires the application installed on a touchscreen that is equipped with a mobile device. Using this application should be simple and involve a selection of icons to describe an event occurring in traffic (traffic lights, pedestrian crossings, slow moving vehicles, bus stops etc.). Each event is represented by an appropriate icon.

Another method of recording is based on voice recognition with commands representing the various types of occurring event. In this case, during the concurrent recording of the GPS track of the vehicle, the commands describing traffic conditions are recognized and recorded. The principle of data recording is similar to the first method, but an application user does not need to press any icons on the touchscreen. This means that data input is safer, as the application can recognize several basic commands describing current traffic conditions.

The testing system allows for recording and evaluating all conditions that can occur during travel, as well as identifying different factors that can decrease speed and extend travel time, such as weather conditions, traffic and congestion levels, traffic lights, roadworks and slow moving vehicles. The results are especially useful for municipal traffic management authorities. In this way, the current settings of road signs and traffic lights, and the influence of the other events, can be examined and verified.

The types of data obtained by the system require additional information from existing traffic management systems, especially the current number of vehicles on the roads. All these aggregated data constitute the basis on which traffic modelling systems obtain optimal parameters.

To obtain highly accurate results, records should be made by several vehicles operating in a selected area of a city. Figure 3 shows the possible data sources for the purpose of further analysis.

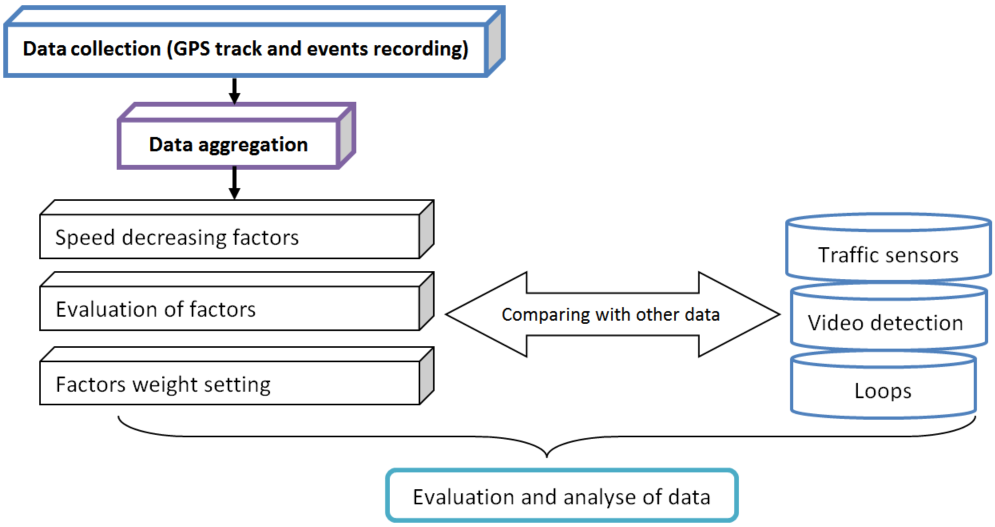


Fig. 3. Event recording and traffic data analysis

Selecting the weight of the factors allows us to evaluate their impact on each section of the road [22,23,24]. In turn, traffic management authorities can modify certain components of the road infrastructure or change the traffic rules. This could be carried out after statistical analysis of the collected data for a selected period of time. Data collected dynamically can be used in real time to update digital map-based systems.

4. PRELIMINARY RESULTS FOR TESTING THE APPLICATION IN GLIWICE

Figure 5 shows a map of Gliwice with the areas of the tests indicated. The city is bordered by two motorways, A4 and A1. Another dual carriageway, No. 902, links the city with other cities in the Silesian conurbation. In the city centre, the old town area has limited traffic, but other roads are often congested during peak hours.

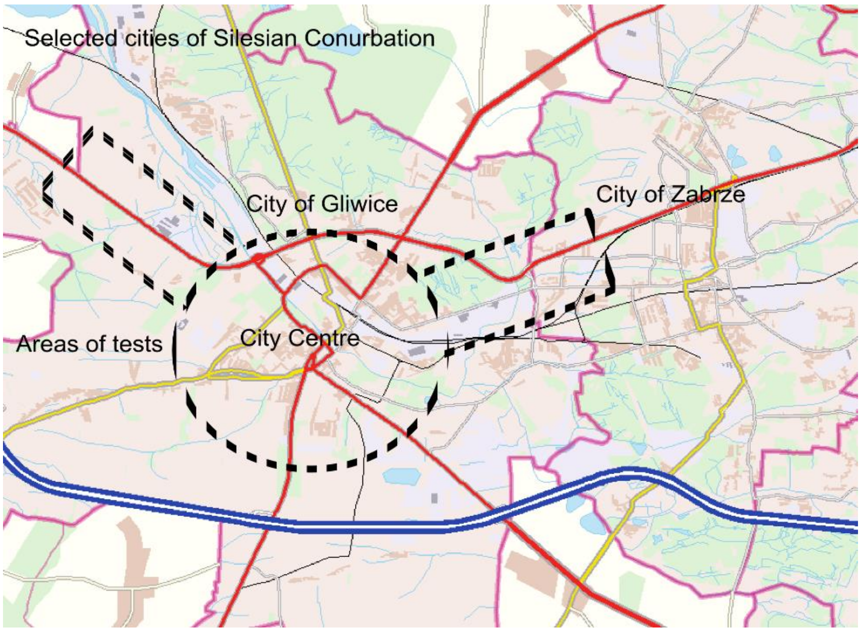


Fig. 4. Test areas in Gliwice

A prototype of an application was used for the tests in Gliwice. The testing vehicle was routed in the loops of the city centre of Gliwice. Recording was provided by a passenger in the vehicle to ensure the safe registration of events. The GPS track was concurrently recorded. The tests were conducted in three different months (March, May and December) during the typical working day (08:00-20:00). The vehicle was routed in a loop along the streets highlighted in Figure 5.

Data recording was conducted in a repeated sequence to minimize errors in changeable traffic flow in continuous loops. After data recording was completed, each section of the track was investigated.

Table 2 shows the distribution of reasons why the test vehicle stopped during the entire study.

Tab. 2

Distribution of reasons why the vehicle stopped in Gliwice's central loop

Vehicle stop reason	**Occurrence in %**
Traffic lights	66%
'Give way' road sign	11%
Pedestrian crossing with traffic lights	9%
'Stop' road sign	6%
Pedestrian crossing	6%
Bus stop	2%

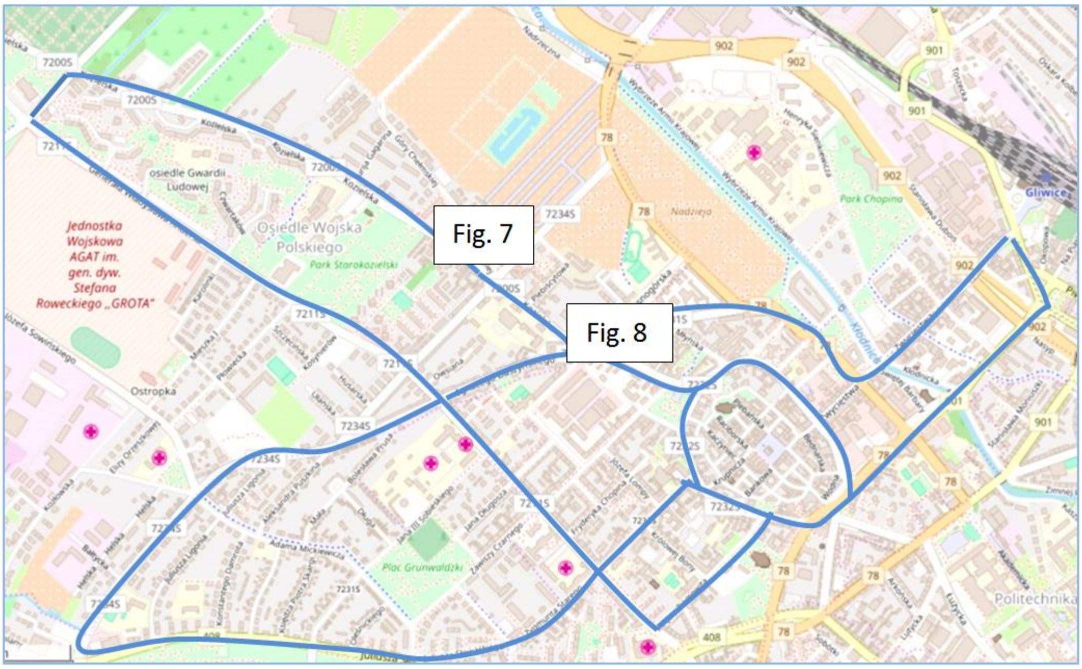


Fig. 5. View of Gliwice city centre with streets used in the routing tests
(driving speed results are shown in Figures 7 and 8)

For the estimation of traffic flow volume, the data from video detectors were analysed. Some of the data collected from traffic cameras on Daszyńskiego Street are shown in Figure 6. These data were used together with the results of the tests to analyse individual sections of each road in Gliwice.

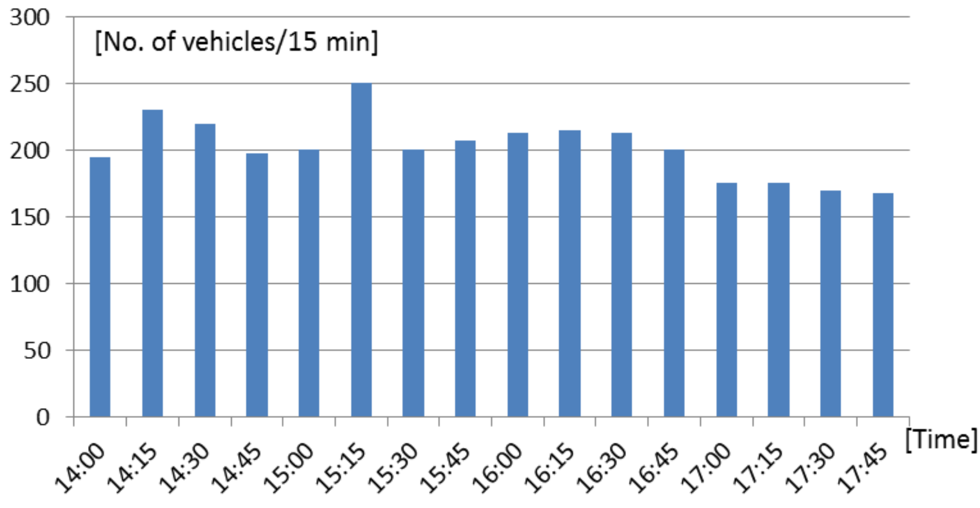
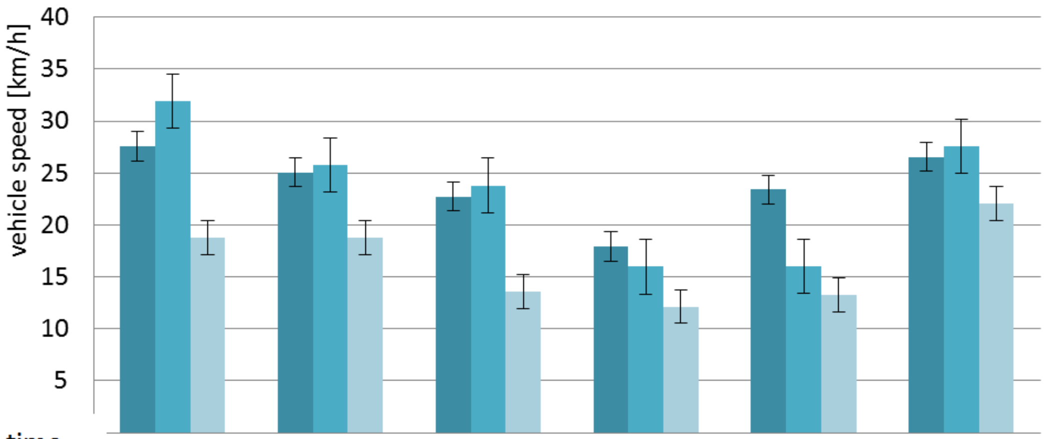


Fig. 6. Total number of vehicles (in both directions) on Daszyńskiego Street

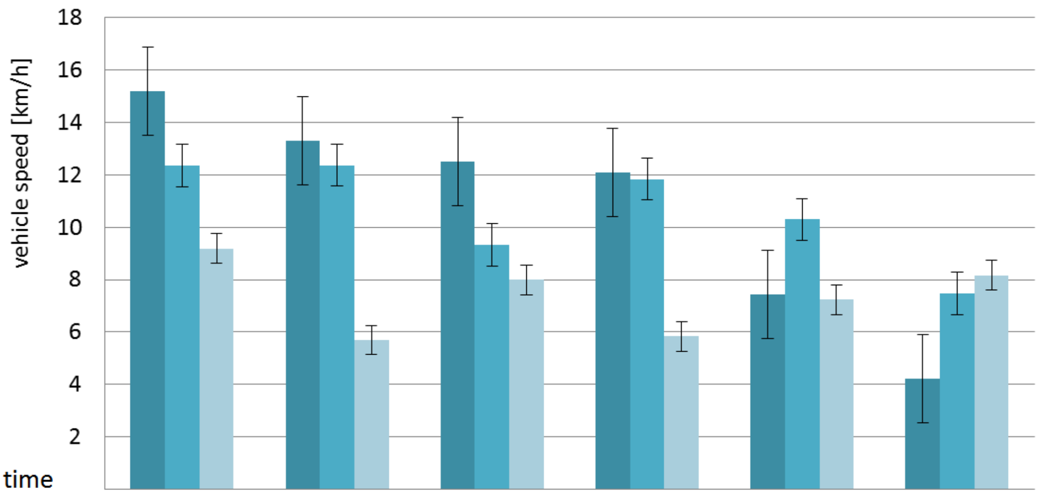
Data collection allowed us to record each event and the consecutive decrease or increase in the vehicle's speed and the total travel time along individual sections of a route. Figures 7 and 8 show examples of the preliminary results for average speed in selected areas (see Figure 5). The results show differences between the March, May and December tests. The main reason was the modernization of the parallel road, Andersa Street, which meant that the average speed for a specific time was lower in May as indicated in Figure 7.



test time	8.00 - 10.00	10.00 - 12.00	12.00 - 14.00	14.00 - 16.00	16.00 - 18.00	18.00 - 20.00
December	27.59	25.07	22.74	17.91	23.39	26.54
March	31.92	25.79	23.79	15.96	16.01	27.59
May	18.78	18.8	13.59	12.13	13.28	22.06

Fig. 7. Decrease in communication speed due to a closed parallel road in the city

Other results relate to a different section of the tested area. The average speed for December was higher than for the other test months (March, May) in time range 08:00-16:00 (Figure 8). In this case, the findings were connected to the closure of several firms at this section of the road during the December holidays (Figure 9). The situation changed after 18:00 when the speed decreased. This was connected with shopping activity at the end of December resulting in increased traffic flow at that time.



test time	8.00 - 10.00	10.00 - 12.00	12.00 - 14.00	14.00 - 16.00	16.00 - 18.00	18.00 - 20.00
December	15.20	13.29	12.52	12.1	7.43	4.21
March	12.35	12.37	9.32	11.83	10.3	7.47
May	9.18	5.69	7.99	5.83	7.23	8.17

Fig. 8. Increased value in communication speed for daytime hours in December due to holidays

5. CONCLUSIONS

A method of traffic data collection, which focuses on why a vehicle decreases its speed or stops offers the opportunity to identify and classify many traffic factors. Such a method is important for the evaluation the current road infrastructure, including road signs and potential hazards for drivers or pedestrians. The results of this study show the potential value of the presented method for the identification of factors can decrease vehicle speed. These data can be supplementary to those provided by traffic data sensors placed in the city. The recorded speeds for routing in the city centre indicate that reaching an average driving speed above 30 km/h is very difficult. In many cases, the driving speed is below 20 km/h or, in some cases, below 10 km/h. Each transportation company delivering goods should be aware of it when planning routes. The proposed application can be equipped with voice commands for recording traffic conditions and vehicle stop reasons. The cost of the proposed data collection is low and the described method has offers traffic management authorities the potential to evaluate traffic conditions in their cities.

References

1. Savrasovs M., Pticina I. 2017. "Methodology of OD matrix estimation based on video recordings and traffic counts". *Procedia Engineering* 178: 289-297. DOI: 10.1016/j.proeng.2017.01.116.
2. Yang H., T. Sasaki, Y. Iida, Y. Asakura. 1992. "Estimation of origin-destination matrices from link traffic counts on congested networks". *Transportation Research Part B: Methodological* 26: 417-434. DOI: 10.1016/0191-2615(92)90008-K.
4. Gartner N.H., C.J. Messer, A.K. Rathi. 1997. *Monograph on Traffic Flow Theory*. Washington, DC: Federal Highway Administration.
3. Duduta N., C. Adriazola, D. Hidalgo, L.A. Lindau, R. Jaffe. 2015. "Traffic safety in surface public transport systems: a synthesis of research". *Public Transport* 7(2): 121-137.
4. Weisbrod G., D. Vary, G. Treyz. 2003. "Measuring economic costs of urban traffic congestion to business". *Transportation Research Record: Journal of the Transportation Research Board* 1839: 98-106.
5. Banister D. 1996. "Energy, quality of life and the environment: the role of transport". *Transport Reviews* 16: 23-35.
6. Pandian S., S. Gokhale, A.K. Ghoshal. 2009. "Evaluating effects of traffic and vehicle characteristics on vehicular emissions near traffic intersections". *Transportation Research Part D: Transport and Environment* 14: 180-196.
7. Ando Y., Y. Fukazawa, O. Masutani, H. Iwasaki, S. Honiden. 2006. "Performance of pheromone model for predicting traffic congestion". In *Proceedings of the Fifth International Joint Conference on Autonomous Agents and Multiagent Systems (AAMAS 2006)*: 73-80.
8. Lee Y.M., S.Y. Chong, K. Goonting, E. Sheppard. 2017. "The effect of speed limit credibility on drivers' speed choice". *Transportation Research Part F: Traffic Psychology and Behaviour* 45: 43-53. DOI: 10.1016/j.trf.2016.11.011.
9. Gargoum S.A., K. El-Basyouny, A. Kim. 2016. "Towards setting credible speed limits: Identifying factors that affect driver compliance on urban roads". *Accident Analysis & Prevention* 95: 138-148. DOI: 10.1016/j.aap.2016.07.001.

10. Topolšek D., T. Cvahte Ojsteršek. 2017. „Do drivers behave differently when driving a car or riding a motorcycle?". *Transport\Transporti Europei* 66(4): 1-16. ISSN: 1825-3997.
11. Viti F., S. Hoogendoorn, L. Immers, C. Tampère, S. Lanser. 2008. "National data warehouse: how the Netherlands is creating a reliable, widespread, accessible data bank for traffic information, monitoring, and road network control". *Transportation Research Record: Journal of the Transportation Research Board* 2049: 176-185.
12. Mínguez R., S. Sánchez-Cambronero, E. Castillo, P. Jiménez. 2010. "Optimal traffic plate scanning location for OD trip matrix and route estimation in road networks". *Transportation Research Part B: Methodological* 44: 282-298.
13. Dion F., H. Rakha H. 2006. "Estimating dynamic roadway travel times using automatic vehicle identification data for low sampling rates". *Transportation Research Part B: Methodological* 40: 745-766.
14. Lu J., L. Cao. 2003. "Congestion evaluation from traffic flow information based on fuzzy logic". In Proceedings: *IEEE Intelligent Transportation Systems* Vol. 1: 50-53.
15. Ashton W.D. 1996. *The Theory of Road Traffic Flow*. London: Methuen & Co.
16. Szczuraszek T. 2008. *Prędkość pojazdów w warunkach drogowego ruchu swobodnego*. Warsaw: Studia z Zakresu Inżynierii; Komitet Inżynierii Lądowej i Wodnej PAN, 2008; ISBN 978-83-89687-39-5.
17. Szczuraszek, T. 2008. *Bezpieczeństwo ruchu miejskiego*. Wydaw: Komunikacji i Łączności.
18. Jägerbrand A.K., J. Sjöbergh. 2016. "Effects of weather conditions, light conditions, and road lighting on vehicle speed". *SpringerPlus* 5: 505. DOI: 10.1186/s40064-016-2124-6.
19. Fleischmann B., S. Gnutzmann, E. Sandvoß. 2004. "Dynamic vehicle routing based on online traffic information". *Transportation Science* 38: 420-433.
20. Henclewood D., M. Hunter, R. Fujimoto. 2008. "Proposed methodology for a data-driven simulation for estimating performance measures along signalized arterials in real-time". In *Winter Simulation Conference*: 2761-2768.
21. Florian M., M. Mahut, N. Tremblay. 2008. "Application of a simulation-based dynamic traffic assignment model". *European Journal of Operational Research* 189: 1381-1392.
22. Schneider W. "Mobile phones as a basis for traffic state information". In *Proceedings: 2005 IEEE Intelligent Transportation Systems, 2005*: 782-784.
23. Dimitriou L., T. Tsekeris, A. Stathopoulos. 2008. "Adaptive hybrid fuzzy rule-based system approach for modeling and predicting urban traffic flow". *Transportation Research Part C: Emerging Technologies* 16, 554-573.
24. Castro-Neto M., Y.-S. Jeong, M.-K. Jeong, L.D. Han. 2009. "Online-SVR for short-term traffic flow prediction under typical and atypical traffic conditions". *Expert Systems with Applications* 36: 6164-6173.

Received 11.10.2017; accepted in revised form 12.01.2018