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TRAFFIC CONGESTION IN CHOSEN CITIES OF POLAND

Summary. The dynamic development of motoring observed in the last two decades contributes to many negative phenomena occurring in road transport. Distinguished among these negative phenomena are high share of car traffic, road accidents, emission of toxic exhaust fumes into the atmosphere, etc. For these reasons, many initiatives are taken in the field of road transport management and city logistics. Traffic problems are solved from many aspects, such as the development of transport infrastructure, changing of urban transport organisation, parking organisation in city centre and Park & Ride system, as well as the progress of alternative means of transport. The problem of traffic congestion in urban areas is still a current topic. This article presents the formation of congestion in urban areas in chosen big cities in Poland. The first part of the article deals with the theoretical issues of traffic flow and congestion formation in the city road networks. The second part of the article outlines the situation of transport congestion with these cities based on the worldwide TomTom Traffic Index within the period of 2008-2016. This study is a brief analysis of the trends relating to the transport congestion based on the TomTom Traffic Index in Polish cities, which will allow future researchers a wider study of this problem. The authors suggest some solutions to reduce the level of transport congestion and harmful emissions from means of transport.

Keywords: city logistics, TomTom Traffic Index, traffic congestion

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1. INTRODUCTION

Transport plays a crucial role in the economy and life of people. Transport infrastructure stimulates the development of the entire economy and creates conditions for its proper development [19, 26]. Transport accessibility of the region is one of the factors that intensify its development [19]. The dynamic development of individual motorisation observed in the last two decades contributes to many negative phenomena occurring in road transport safety and negative impact on air quality in agglomerations. Environmental impacts of transport are unfavourable and they often have unavoidable character [28]. One way to reduce pollution production is to operate more environmentally friendly vehicles [17, 18, 30] or used alternative fuels for supply internal combustion engines [5]. The problem of road transport safety is a constant issue undertaken by the scientific community, as evidenced by numerous publications in this area: [2, 3, 7, 9, 11, 13, 20-22, 25, 29, 32, 36]. Car travel is related to climate change, depending on fossil fuels, and traffic congestion [8]. Extending travel time caused by decreasing the average vehicle speed, unfavourable weather conditions (high ambient temperature, icing or intense snowfalls) adversely affect the psycho-physical state of the driver, and consequently, may lead to wrong decisions and situations of danger (traffic accident) [6].

Road traffic congestion is arguably the main problem of the transport system [16]. Congestion causes global concerns, such as increased commuting times and fuel usage as well as environmental deterioration [35]. The negative effect caused by traffic congestions is most notable in the largest cities, where traffic density is relatively high, with characteristically low and often variable speed (acceleration and deceleration) [24]. While there are considerable technological and policy opportunities for tackling detriments associated with pollution from vehicle emissions and road traffic accidents, congestion seems a more intractable challenge [16]. Understanding the process of traffic flow and detecting traffic congestion are important issues associated with developing urban policies to resolve the problem. Among the causes of traffic congestion, we can differentiate physical and psychological factors. Physical causes measure traffic, speed and density of the street. Psychological factors are more difficult to measure and each driver accepts a different level of congestion. Some people accept slight traffic congestion, whereas others do not, and this causes more stress for them.

Traffic congestion is a complex spatial-temporal process [12]. Congestion can be recurrent (regular, occurring on a daily, weekly or annual cycle) or non-recurrent (traffic incidents, such as accidents and disabled vehicles) [14]. Congestion in the urban zone can be considered as a phenomenon on a local and global scale. Local congestion, such as single interactions, only decreases the velocity of individual vehicles, whereas global congestion often decreases the velocity of the overall street network and requires additional traffic control [34]. William Vickrey identified six types of congestion [34]:

- Simple interaction on homogeneous roads: where two vehicles travelling close together delay each other.
- Multiple interactions on homogeneous roads: where several vehicles interact.
- Bottlenecks: where several vehicles are trying to pass through narrowed lanes.
- "Trigger neck" congestion: when an initial narrowing generates a line of vehicles interfering with a flow of vehicles not seeking to follow the jammed itinerary.
- Network control congestion: where traffic controls programmed for peak-hour traffic inevitably delay off-peak hour traffic.

- Congestion due to network morphology, or polymodal polymorphous congestion: where traffic congestion reflects the state of traffic on all itineraries and for all modes. The cost of intervention for a given segment of roadway increases through possible interventions on other segments of the road, due to the effect of triggered congestion.

As earlier mentioned, congestion in the urban transport network is common in large agglomerations as well as in medium-sized cities. This is a phenomenon characteristic of cities with a high level of socio-economic development on all continents. In cities, we usually deal with a large concentration of transport needs in time and space that occur with a certain periodicity and is particularly severe in city centres. Transport of cargos via small commercial vehicles within Central Europe is very popular [15]. Vehicles of this type limit visibility to other road users, take up a lot of space and need to manoeuvre, which is particularly severe in crowded city centres.

Currently, the large possibilities of increasing the capacity of traffic flow are due to the use of intelligent transport systems for traffic control. In many countries of Central Europe, intelligent transport systems operate with great success, similarly, in Poland, an increasing number of cities implement these systems to improve the efficiency of vehicle flow control. Many cities decide on alternative means of transport (for example, city bike system, development of a trolleybus network). Transport companies are considering investing in hybrid vehicles. The possibilities of minimising fuel consumption and reducing the emission of toxic compounds from hybrid public transport vehicles are shown in [1]. However, in the works [4, 23, 27, 31], information can be found on selected aspects of the operation of hybrid drives in passenger cars. Increasingly, hybrid vehicles are used in taxi corporations and car-sharing companies. Some local governments decide to invest in the Park & Ride system and free public transport for people who have used the Park & Ride system (for example, Katowice), or specially designated bus lane on the road for an urban bus (for example, Warsaw and Lublin). Some of the cities introduced a division into paid parking zones in the city centre with a diverse tariff (for example, Lublin) and limits access to city centres for vehicles powered by diesel engines (for example, Berlin).

2. SHORT ANALYSIS OF TRAFFIC CONGESTION

2.1. Methodology and data

The research methodology was based on measurement tests Worldwide Congestion Ranking data TomTom Traffic Index (TTTI) for 6 chosen Polish cities. The TomTom Traffic Index is published to provide drivers, industry and policy makers with unbiased information about congestion levels in urban areas [33]. The data for the analysis was obtained from the TomTom Traffic Index reports, published on the website [33], for the compared cities.

To avoid misunderstandings during data analysis, the terminology used in the research should be presented and defined. The definitions given below are based on TTTI and used in this paper.

World rank of TomTom Traffic Index can be defined as the rank of the cities with a population greater than 800,000 [33] and 2 million inhabitants, however, there are data for smaller cities in the TomTom Traffic Index program, which do not enter the global comparison. The ranking is based on the Congestion level (extra travel time) [33].

Congestion level can be defined as an increase in overall travel times when compared to a Free Flow (uncongested) situation [33].

Extra travel time can be defined as extra travel time during peak hours versus an hour of driving during a Free Flow (uncongested) situation [33]. Multiplied by 230 days for the annual figure.

Morning peak can be defined as an increase in morning peak travel times when compared to a Free Flow (uncongested) situation [33].

Evening peak can be defined as an increase in evening peak travel times when compared to a Free Flow in an uncongested situation [33]. The hours of morning and evening peak may vary in different cities and depending on the day of the week. In most cases, within the week, they are the same for the city in question.

Road network length is the total length of the evaluated road network, including highways and non-highways expressed in kilometres or miles.

Live traffic delay is the current total time of delays in all jams on all monitored roads in the city area.

Live traffic speed is the current average speed on all monitored roads in the city area based on the TomTom Traffic Flow information [33]. The last two parameters include highways and major roads and minor roads.

2.2. Comparison of the TomTom Traffic Index in 6 Polish cities

This section presents the results of research for 6 chosen Polish cities, these are Warsaw, Wroclaw, Cracow, Poznan, Lodz and Szczecin. A characteristic feature of all Polish metropolises is a dynamic increase in the level of motorisation of society and a decrease in the volume of transport in public transport. Consequently, the number of cars per capita and the intensity of street traffic is still increasing, leading to the occurrence of congestion and a significant increase in travel time. According to Eurostat data, in 2015, the motorisation rate in Poland amounted to 546 cars per 1000 inhabitants, compared to 323 in 2005. This means that currently, statistically more than every second Pole has a car.

The examination of occurrence of congestion was based on the measurement of the speed of passage of particular sections of roads, determined based on GPS data collected in real-time from moving vehicles. For individual cities, average delays were calculated due to congestion (extra travel time), the average speed of vehicles during communication peaks on the entire road network covered by the survey (and optimal traffic speed) and the largest bottlenecks were examined. The delay indicator due to congestion was calculated in relation to the free passage time without any difficulties. Historical data on congestion in the six largest cities in Poland are included in Tab. 1.

When analysing the data presented in Tab. 1, it can be stated that in 5 of 6 cities there was a reduction in the level of traffic congestion. Unfortunately, only in two cities, Wroclaw and Cracow, the level of congestion clearly decreased by as much as 12%. In other cities, the level of congestion decreased by much smaller values. In Warsaw by 3%, Poznan by 6% and in Szczecin by 4%. In the case of Warsaw, a slow decline in the level of congestion since 2011 can be observed. The largest decrease in the congestion level in year-on-year terms was recorded in the cities of Wroclaw and Cracow amounting to 13% in 2011.

The analysis of the data shows that the worst situation is in the city of Lodz. Over the years, the level of congestion increased from 47 to 51% in 2016, and the highest level of congestion was recorded in 2014. In the case of Lodz, the positive aspect is only that compared to the previous year in 2016, there was a decrease in the congestion level by 3%.

Tab. 1
Congestion level history in compared cities expressed in % by Extra travel time

City	2008	2009	2010	2011	2012	2013	2014	2015	2016
Warsaw	40	43	48	45	41	39	40	38	37
Wroclaw	47	47	50	37	30	32	35	35	35
Cracow	48	41	50	37	31	33	34	35	38
Poznan	40	39	43	41	36	33	35	34	34
Lodz	47	51	53	47	46	52	56	54	51
Szczecin	28	26	27	28	29	24	27	26	24

Authors' study based on [33]

During the analysed period, it can be stated that only for one city (Szczecin), the situation regarding extra travel time could be considered as stable. Szczecin is also a city in which the level of congestion is clearly the lowest compared to other cities.

In Fig. 1 is presented the congestion level for the compared cities in 2016, including morning peak, evening peak, length of highways and non-highways (major and minor roads).

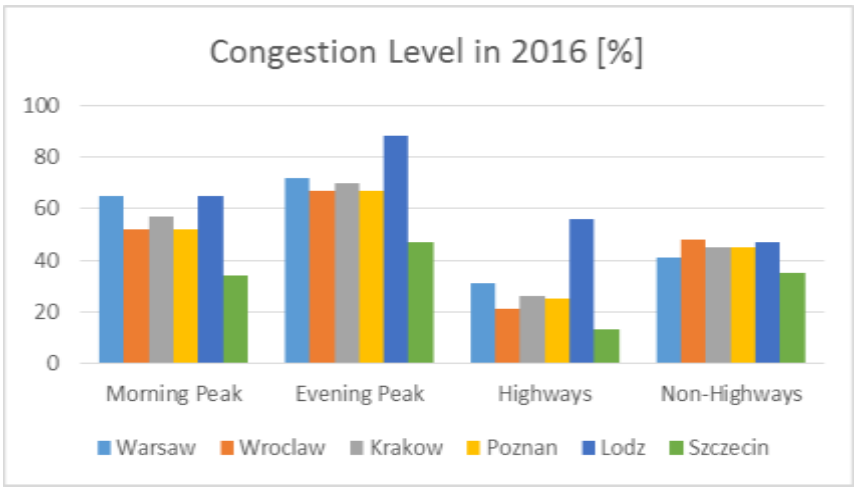

Fig. 1. Congestion level for compared cities in 2016
Authors' study based on [33]

As shown in Fig. 1, in all analysed cities, the highest level of congestion is in the Evening Peak. The lowest level of congestion is noticeable at highways; the reason for this situation may be much higher throughput and definitely greater fluidity of the flow of vehicles than on other roads. Only in Lodz, the situation is different, the greater level of transport congestion occurs here on highways. Furthermore, as can be seen in Fig. 1, for almost all of the analysed parameters, the largest percentage level of transport congestion occurs for the city of Lodz.

In Fig. 2, is presented Extra travel time for the compared cities in 2016. The presented data show that the worst situation is in the city of Lodz and Warsaw. The average additional time expressed in minutes is over 40 minutes. The lowest level for these parameters was recorded in Szczecin.

Fig. 2. Extra travel time per day and year, for compared cities in 2016
Authors' study based on [33]

In Fig. 3, optimal traffic speed level for compared cities in 2016 is presented.

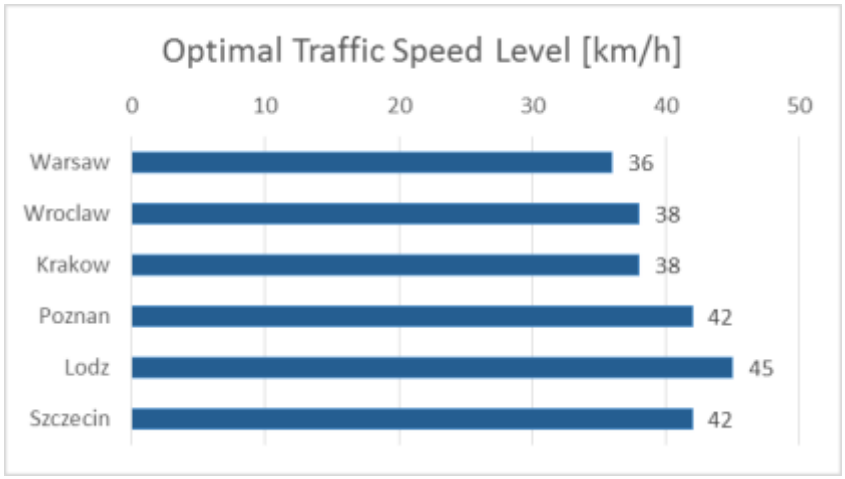

Fig. 3. Optimal traffic speed level for compared cities in 2016
Authors' study based on [33]

In all analysed cities, during traffic congestions, there are average speeds of trips below the optimal traffic speed (Fig. 3).

4. CONCLUSIONS

Congestion in urban areas is currently one of the most pressing problems in transport [12]. The phenomenon of congestion is particularly onerous for users of traffic (individual drivers, suppliers of stores and institutions, couriers, etc.), and indirectly affects the well-being of agglomeration residents as well (that is, noise, air quality).

With the current level of demand for transport and the development of individual motorisation, the complete elimination of congestion in cities seems to be impossible to achieve. Therefore, the commonly accepted course of action is to bring traffic congestion to an economically justified and acceptable level. Several measurements could significantly

reduce congestion in the city: the implementation of various telematics systems as well as the correct setup and synchronisation of traffic light signalling at intersections (that is, creating a "green wave"); increasing the capacity of roads and construction of others; traffic regulation; limiting the right of entry to certain areas or charging of the traffic within the city areas [10]. The comparison of several selected Polish cities shows that it is possible to reduce the level of traffic congestion in the urban area. Efforts that are made by municipal authorities bring positive effects, however, it is an ever-changing environment, susceptible to transport disruptions. Effective management of traffic flow in the city is a very difficult and demanding task, nonetheless, extremely necessary to modern agglomerations.

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