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EFFICIENCY OF URBAN CONGESTION PROBLEM SOLVING

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ABSTRACT. Background: Traffic congestion is nowadays probably one of the greatest problems of urban transportation systems and infrastructure. Unfortunately, it frequently happens that road work investments connected with the construction of new and re-construction of old road networks, contrary to original intentions, fails to improve urban transportation or even deteriorate it significantly.

Methods: The article presents an analysis of some methods of easing urban traffic congestion. Instrumental methods such as city center parking tolls usually do not bring about situation improvement. Introducing a faster and relatively comfortable public transportation competitive with commuting by cars is more efficient.

Results and conclusions: The results of the research also reveal that the frequently applied method of road broadening does not lead to increasing their capacity as it fuels the preference for using private cars, instead of means of mass transportation. Consequently, the number of cars driving in towns and cities is larger and the level of congestion boosts. Uncoordinated individuals striving towards achieving their personal optimum are not always achieving optimum for the whole community. Communities as a result of that tendency must pay the Price of Anarchy. Therefore, the better mass transportation functions, the more persons start using it and simultaneously there will be fewer cars in the network of streets and transportation routes - with the resultant lower level of congestion.

Key words: flow of persons in cities and towns, urban traffic congestion, instruments of urban management, price of anarchy.

INTRODUCTION

A phenomenon of congestion resulting from the division of cities and towns into various functional areas and the necessity for the movement of people arising from there seems to be present in pertinent literature almost as an axiom [Rodrigue, Comtois, Slack 2006]. It is nowadays probably one of the greatest problems of urban transportation systems and infrastructure. Traffic congestion is usually defined as an excessive increase in the number of vehicles on roads which may lead to the overloading of transportation networks [Pawlak Z. 2007] and the appearance of numerous social, economic and environmental problems connected with it and consequently may even result in the stoppage of flows. Unfortunately, it frequently happens that road work investments connected with the construction of new and re-construction of old road networks, contrary to original intentions, fail to improve urban transportation or even deteriorate it significantly.

INSTRUMENTAL EASEMENT OF URBAN CONGESTION

The research carried out worldwide reveals that workers' and students' commuting is a dominant factor increasing urban congestion [Asensio 2002]. This poses a difficult dilemma - How can this problem be solved? Some researchers suggest that the best solution would be a more concentrated

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urban spatial structure [Nijkamp, Ouwersloot, Rienstra 1997]. Others, however, point out [Downs 2004] to a general need to change work time hours in order to diminish the number of commuters in traffic peak hours. Both approaches seem to be very radical and require very dramatic changes in the urban spatial structure, transformations of social and economic relations and even reversing advanced decentralization processes. In the light of so extreme approaches a rational adaptation of already existing urban modelling factors seems to be more feasible. Therefore, providing environment-friendly, speedy and relatively comfortable public transportation which would be able to compete with cars is considered reasonable and implementable.

Undoubtedly, one of the possible solutions facilitating the easement of traffic congestion problems is altering preferences of a significant part of car users and directing them towards other (alternative) means of transportation. Although the advantages of public transportation such as safety, environmental-friendliness and better transportation capacity are commonly known, the opinions of sceptics who claim that the impact of means of mass transportation on the total efficiency of urban transportation network may be limited for instance by the level of transportation infrastructure development.

Against all appearances, road works carried out in most cities and towns all around the world and aiming at broadening the streets do not result in increasing road capacity. In accordance with the Lewis-Mogridge Position [Bell, Wichiensin 2012] - traffic expands to meet the available road space. Thus, road capacity gains subsist for a few months the longest, and sometimes they disappear even within a few weeks. The problem of congestion comes back and drivers are stuck in traffic jams on a larger number of road lanes. The research carried out by the author in the urban agglomeration of Poznań (Poland) which focused among others on the dynamics of the flow of persons in transport corridors [Pawlak 2011], reveals that the number of vehicles going on a given street during peak hours equals the number of road lanes multiplied by 1300. Thus, the observation that additional lanes attract additional vehicles is confirmed. Therefore, the system of urban road infrastructure shall be considered as a unity rather than a set of separate sections. It should also be borne in mind that an excess of road investments, especially carried out at the same time, in city centers very often paralyses towns and cities. Inhabitants, who affect urban space vitality, lose their place and privileges due to them. For instance, they have to continuously wait at traffic lights, walk along narrow pavements and breathe exhaust fumes. Vehicles and public space are hard to harmonize - especially in often historic city centers.

Among instruments which may be used to encourage (or discourage) people to commute individually in cars which are most frequently applied by authorities of towns and cities there are the following ones:

- introduction of efficient public transportation such as commuter trains with Park & Ride systems,
- collection of congestion charges,
- increase in parking tolls, and
- simultaneous introduction of congestion charges and park tolls increases.

The research carried out by the author has revealed that additional instruments regulating flows [Pawlak 2011], may reduce modelled level of cars used for the purpose of commuting even below 20% of initial traffic volume. Sometimes it is enough to implement efficient public transportation to make a major part of commuters resign from using their cars. Congestion charges have also a greater impact on the reduction of the number of cars used than parking tolls. Consequently, it should come as no surprise that the combination of both solutions results in a synergy effect, that is to say, the final result of their implementation is better than their direct sum. It should be borne in mind, however, that the accrual is not significant, as a rule, as it usually refers to the same group of people. It frequently happens that inhabitants prefer using their own cars for commuting despite the introduction of congestion charges in urban areas. If that is the case, some other instruments need to be applied. One of such instruments is a parking toll. Copenhagen may serve as an example of an efficient solution implemented in this respect. In this Danish city parking tolls are calculated so as to have 10% of parking spaces left free. When the percentage decreases, parking tolls are increased. The authorities of Copenhagen do not try to provide the inhabitants of city centers with parking spaces as it is not the task of municipalities. The fact that someone owns a car is not a prerequisite for a right to a parking space (even next to one's house). The inhabitants of Tokyo have understood this principle very well for a long time as before having a car registered its owner must indicate the place where the car is to be parked.

THEORETICAL AND PRACTICAL EFFICIENCY OF REDUCING URBAN CONGESTION

In accordance with a theoretical approach of Downs-Thomson and Pigou-Knight-Downs [Downs 2004] the average speed of a person travelling by car in urban areas depends on the average speed (door-to-door speed) of a person travelling by means of public transportation. In other words, the better public transportation is, the more persons will use it and consequently there will be less cars present on the network of streets and urban communication tracks and as a result there will be fewer traffic jams. Therefore, depriving drivers of one lane and reserving it for buses or tram tracks solely, in fact, decreases rather than increases traffic jams (congestion). It directly results from the capacity of certain street lanes. It may be easily calculated that people gathered in cars and stuck in huge traffic jams may be easily transported for instance in a few trams. In accordance with the results of the research undertaken by the author of this paper for the agglomeration of the city of Poznań (Poland) there are about 167 people in one tram during peak hours, and at the same time there are on average 6 persons sitting in 5 cars (1.2 person per car). Both the tram and cars in question occupy the same transportation space on roads.

Providing efficient public transportation may be a very beneficial tool of improving urban passenger transportation systems. But the mere presence of buses, trams or commuter trains does not lead automatically to balancing the systems better. The term balancing encompasses multi-aspectual optimization which results from a long-term interaction among economic and non-economic efficiency factors. Ignoring those factors, especially the social culture and behavioural traditions, may lead to a failure of municipal policy aiming at diminishing urban congestion. For instance, drivers in countries where people are strongly attached to their cars, e.g. the USA, may be less receptive to the idea of travelling by means of public transport only because such means are available. Thus, it may even lead to the increase of the number of cars on roads and consequently it may boost the level of congestion. This situation is called Braess's paradox [Quinet, Vickerman 2004] (it consists in the fact that adding extra capacity, extra link to a transportation network results in the increase of the general social transportation cost) and may constitute a very serious obstacle to balancing urban passenger transportation. There are, therefore, situations in which increasing the capacity of the urban road and street network brings about the lengthening of the average flow time and decreasing general efficiency of the transportation network.

For instance, let us assume that we have a network with four vertexes and four edges. Each edge represents a road and the cost connected with travelling along the road is expressed in time needed to do so. It is obvious that the drive time for a given road depends on the road's quality (mainly the number of junctions).

Let us assume that the routes N-W and E-S are safe and have a high capacity and the average time needed to cover the routes does not depend on the number of vehicles and amounts to t_1 = 30 minutes. The route N-E and W-S are local roads of a lower capacity in case of which the time needed to drive depends linearly on the number of vehicles and amounts in minutes to t_2 = P/100, where P is the number of vehicles present on the network. For calculation purposes P=2000 vehicles.

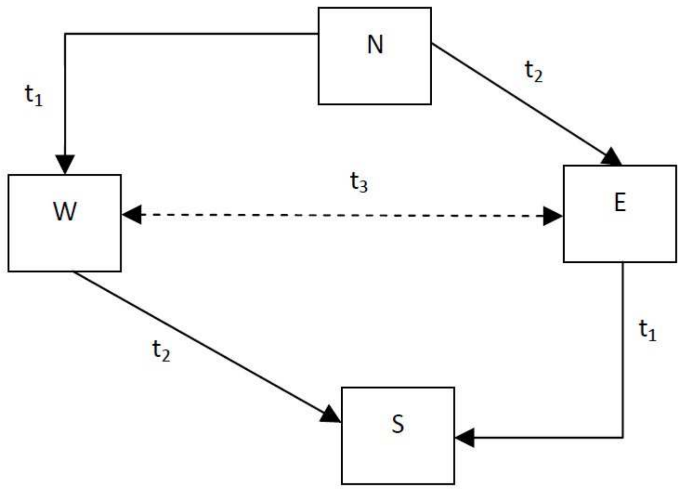

Fig. 1. Road network
Rys. 1. Sieć dróg

Let us now calculate the average drive time (T) between N and S. As both routes (through E and W) are identical as far as the cost and length are concerned, each driver aims at minimizing his own cost. That is why there is a high distribution probability that one half of drivers will choose route E and the other half route W.

So let us calculate now the average drive time:

for N-W-S it amounts to: $T_{NWS} = t_1 + 0{,}5\ t_2$

T_{NWS} = 30 min + 10 min = 40 min

and for N-E-S it amounts to: $T_{NES} = 0{,}5\ t_2 + t_1$

T_{NES} = 10 min + 30 min = 40 min

Let us assume that a new high-capacity road has been built between E and W. In order to simplify the calculation and show the result more clearly let us assume that in the case of that new road the drive time amounts to t_1=5 minutes and is irrespective of the number of vehicles.

Let us now repeat the calculation for the new route (T`).

Travelling from N to S each driver will be able to choose either route N-E or N-W. As the number of cars in the network is P=2000, the worst time scenario in the case of route N-E amounts to:

$T`_{NE} = t_2$ = 20 min

and in the case of route N-W amounts to:

$T`_{NW} = t_1$ = 30 min

Thus, all the drivers will choose the first variant. Next, they will face a similar dilemma and out of the two E-W-S ($T`_{EWS} = t_3 + t_2$ = 25 min) or E-S ($T`_{ES} = t_1$ = 30 min) they will choose E-W-S, to minimise their personal drive time.

The average total drive time from N to S along the N-E-W-S route will amount now to:

$T`_{NEWS} = t_2 + t_3 + t_2$ = 20 min + 5 min + 20 min = 45 min

It may easily be noted that after the construction of a new route the average drive time increased (deteriorated) by 5 minutes. None of the drivers will change his route as the initial routes N-E-S or N-W-S take now:

$T`_{NES} = T`_{NWS} = t_1 + t_2$ = 30 min + 20 min = 50 min

that is 5 minutes more,

and the route N-E-W-S shall take:

$T`_{NWES} = t_1 + t_3 + t_1$ = 30 min + 5 min + 30 min = 65 min that is 20 minutes more which constitutes 25 minutes more from the shortest time (amounting to 40 min) in the case of T_{NES} and T_{NWS} present before the construction of a new road.

The analysis presented above shows that uncoordinated individuals aiming at achieving their own personal optimum are not always contributing to achieving optimum for the whole community. That is why society must pay the so-called Price of Anarchy (PoA) [Youn, Gastner, Jeong 2008], connected with the lack of coordination between certain individuals.

In order to limit the impact of the Price of Anarchy, in many European cities (with London in the lead) derivative methods are introduced. They include closing some streets and collecting charges for driving in city centers. The latter shall be calculated in order to balance preferences of individuals to achieve efficient balance (social optimum) in this respect.

CONCLUSIONS

To sum up, contrary to expectations in the majority of cities and towns all around the world investments connected with constructing new and developing old roads, fail to improve transportation or even make the situation worse.

The reduction of traffic congestion problems is usually achieved by changing preferences of the largest possible number of car users and convincing them to use alternative means of mass transportation.

But, the introduction of the efficient network of public transportation does not seem to be sufficient encouragement for the majority of commuters who prefer their own cars. The research reveals that congestion charges have a stronger influence on diminishing the number of private car users than parking tolls. Therefore, the combination of the two solutions gives the effect of synergy that is to say the end result of their application is better than their direct sum. It should be emphasized here, however, that the accrual is usually not very significant as it refers to the same group of people. Moreover, not taking into consideration factors connected with social culture and traditional behaviours may result in a failure of municipal policy striving towards decreasing urban congestion.

Social costs of traffic congestion in urban areas are often increased by the so-called Price of Anarchy which stems from the fact that individuals (users of cars) pursue their personal optimum which is usually not the same as social optimum for the community of a given city or town (municipality).

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EFEKTYWNOŚĆ ROZWIĄZYWANIA PROBLEMÓW KONGESTII DROGOWEJ

STRESZCZENIE. **Wstęp:** Kongestia drogowa jest obecnie jednym z najpoważniejszych problemów miejskich systemów komunikacyjnych i ich infrastruktury. Zdarza się inwestycje w infrastrukturę drogową, połączone z budową nowych lub przebudową starych połączeń drogowy, nie przynosi oczekiwanych rezultatów, tzn. nie przynosi poprawy stanu komunikacji miejskiej a nawet go pogarsza.
Metody: W artykule poddano analizie niektóre metody łagodzenia kongestii drogowej w obszarach zurbanizowanych. Metody instrumentalne, na przykład opłaty za parkowanie w centrach miast, nie przynoszą zwykle poprawy sytuacji. Bardziej skuteczne okazuje się wprowadzenie szybkiego i względnie komfortowego transportu publicznego, który byłby w stanie konkurować z przejazdami samochodami osobowymi.
Wyniki i wnioski: Z badań wynika również, że stosowane często poszerzanie dróg, nie prowadzi wcale do zwiększenia ich przepustowości, gdyż wzmaga preferencje do używania samochodów prywatnych, zamiast środków komunikacji zbiorowej. W konsekwencji, prowadzi to do powiększenia liczby pojazdów poruszających się po mieście i tym samym wzrostu poziomu kongestii. Nieskoordynowane jednostki dążące do osiągnięcia swojego osobistego optimum, nie zawsze osiągają w ten sposób optimum dla całej społeczności, która musi w konsekwencji płacić tzw. cenę anarchii. Im lepiej zatem będzie funkcjonowała komunikacja zbiorowa, tym więcej osób będzie jej używać, a tym samym w sieci ulic i tras komunikacyjnych miasta będzie mniej samochodów - z czego wyniknie mniejszy poziom kongestii.

Słowa kluczowe: przepływy ludności w miastach, drogowa kongestia miejska, instrumenty zarządzania miastem, cena anarchii

EFFIZIENZ DER PROBLEMLÖSUNG VON ÜBERFÜLLTEN VERKEHRSSTRAßEN

ZUSAMMENFASSUNG. Einleitung: Überfüllte Straßen stellen heutzutage eines der ernsteren Probleme für städtische Verkehrssysteme und deren Infrastruktur dar. Es kommt vor, dass die Investitionen in die Straßeninfrastruktur verbunden mit Aufbau von neuen oder Umbau von alten Straßenverbindungen, keine erwarteten Resultate mit sich bringen, d.h. keine Verbesserung des städtischen Kommunikationssystems und sogar dessen Verschlechterung zur Folge haben.
Methoden: Im vorliegenden Beitrag wurden einige Methoden für die Milderung der mit überfüllten Straßen verbundenen Nachteile in den urbanisierten Ballungsgebieten einer weitgehenden Analyse unterzogen. Die instrumentalen Methoden wie etwa Parkgebühren in den Stadtzentren bewirken gewöhnlich keine Verbesserung der Situation. Es stellt sich dagegen heraus, dass die Einführung von schnellen, relativ komfortablen, öffentlichen Transportmitteln, die mit dem Transport mittels PKWs zu konkurrieren vermögen, viel wirksamer wird.
Ergebnisse und Fazit: Aus den betreffenden Forschungen geht hervor, dass die oft forcierte Verbreiterung von Verkehrsstraßen auch zu keiner Vergrößerung deren Kapazitäten führt, sondern bei Reisenden den Gebrauch von PKWs statt der Inanspruchnahme von öffentlichen Verkehrsmitteln steigern lässt. In Folge dessen führt das zur Erhöhung der Anzahl von den in der Stadt verkehrenden PKWs und gleichzeitig zum Anstieg des Stauverkehrs in Stadtzentren. Unkoordiniertes Verhalten von Privatpersonen, die nur ihr persönliches Wohl anstreben, verfehlt dadurch das Optimum der ganzen Verkehrsgemeinschaft, welche in der Konsequenz den sog. Anarchie-Preis zu bezahlen hat. Je besser also das öffentliche Verkehrswesen in Funktion tritt, desto mehr Personen es in Anspruch nehmen, wodurch es auch im Straßenverkehrsbetz weniger Privatautos geben wird - was im Endeffekt das Niveau der Verkehrs-congestion senken lässt.

Codewörter: Personenfluss in Städten, überfüllte Verkehrsstraßen, Instrumente für städtisches Verkehrsmanagement, Anarchie-Preis

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