

Sustainable Urban Transport System Development Reducing Traffic Congestions Costs

Arturas Kersys

*Kaunas University of Technology
Kestucio str. 27, LT-44312, Kaunas, Lithuania
e-mail: arturas.kersys@ktu.lt*

Traffic congestions are formed due to irrational city facilities in communication terms and improper traffic system's facilities; improper crossings of streets with intense traffic; absence of high-speed continuous traffic main streets; no passenger traffic parking lots in the largest routs. In consequence of congestions there arises increasing pollution, impairment of people health and economic loss.

Investigation of traffic flows is complex multidimensional task, solution complication of which depends on complexity extent of transport network. In order to analyze the particularity of forming congestions, investigation describing in details the interaction of vehicles and road facilities are necessary.

The main research purpose is to determine vehicle's waste of time with flow close to system overcrowding or moving in congestion. In order to evaluate congestions expenses and rare occasional loss many parameters and assumptions are necessary, because these parameters are expressed by physical expressions. The most important of them are: value of travel time is used to convert time loss and/or reduced reliability and comfort into monetary units; variation of demand, defining reaction of possible consumers to internalization of exterior expenses of congestions.

Expenses evaluation methods used are based on the evaluation of travel time. To this end lots of investigations have been performed in various European countries. Actually experts are inclined to use general VOT values for public and goods traffic. Traffic flow intensity is determined by specified averages traffic flow speeds in separate sectors, travel time and, the main thing, defining sector throughput. Flow particularity has been determined, as well, i.e. impact of a number of lanes and evaluated wasted time with different intensity of vehicles flow.

Having data on traffic flows, it is possible to determine frequency of arriving and outgoing vehicles and time intervals between them and evaluate situation in a crossing. Schemes of vehicles movement were formed, projecting the arrival of vehicles one by one or by blocks, and data on flows directions and intensity collected. According to queue extent it is possible to judge about quality of traffic control system and loading of crossing with transport and forecast possible congestions.

After the analysis of some transport flows in the city traffic, investigation of traffic congestions reasons, these conclusions could be made: there is no methodical facilities development programme of the city streets; roads with intense traffic crossings of the city are old-fashioned,

and their throughput is three or four times smaller than streets throughput and traffic flows intensity; there is no high speed public traffic service created and this becomes a pretext to use an individual transport, increasing traffic intensity and traffic congestions; there is no reverse lanes in the streets with intense traffic, what could increase road throughput and no public transport traffic lights before crossings, which at least would reduce, congestions of this traffic.

Sustainable urban traffic system development reducing congestions costs shall be based on long term "sustainable people and goods mobility vision".

Keywords: *urban transport, sustainable development, traffic congestions, external costs.*

Introduction

In a most important European economy parts - transport sector about 7 % of CIP there is produced and more than 5 % of EU working places are guaranteed (2009). Admitting transport importance in order to achieve social and economic cohesion of regions, European and world, assuring European industry ability and realizing Lisbon's objectives, it could be stated that some fields of European transport system still do not meet the objectives of sustainable development.

Mobility and transport activity scale is growing in the world due to the increment of population and improvement of life quality (Cruzado, 2005, Ciegis, 2009, Kazlauskaitė, 2008, Kilijonienė, 2010, Startienė, 2009). Amount of motorcars in the world might increase from approximately 700 mln at present up to more than - 3 mlrd in 2050 and if there are no vehicles less polluting environment or quite environment-friendly ones and a new mobility conception is not developed, big harmony and husbandry problems will arise.

In urban traffic policy till now there was the most important aspect – to meet traffic request, even a new request. Traffic needs were developed, because, firstly subsidies in economic aspect were granted to individual motor vehicles, economic division of labor was supported just taking into account the possibility of getting cheap oil and producing places and settlements.

It is very important to set, what political and planning solutions decide the formation of traffic flows and how it could be avoided (Baltrenas, 2009, Button, 2005, Cygas, 2009). During latter years some opinions were created on the optimization of various traffic policy areas and technical

and organizational control of traffic flows (Bickel, 2006): “Exterior expenditure of internalization realization strategy“, “Mobility actions plan in the city“, “Road traffic 2020“.

While preparing new mobility conception it is important to investigate comprehensively the problems of the formation of traffic flows and compulsory mobility. Discussion on the nature of stable development strategy is necessary, because in this strategy till now traffic policy there was integrated insufficiently, thus ensuring possibility for future generations of using mobility freedom (Ciegis, 2009, Litman, 2001, Zuidgeest, 2006).

Research problem: investigation of possibilities to reduce factors conditioning forming of traffic jams in urban traffic network and costs caused by them.

Research objectives: to perform investigation of traffic congestions in urban traffic network and to find out part of congestions costs, evaluating waste of time and fuel consumption.

Research subject: traffic flows, congestions expenses, sustainable development of urban traffic system.

Research methods: natural traffic flows investigation, systemic analysis of scientific literature, statistical data grouping and comparative analysis.

Reasons of traffic congestions formation in an urban transport system

The main problem in Lithuania, as in all countries, there exists traffic congestions, formed because of these reasons (Butkevicius, 2005, Ilgakojoyte-Bazariene, 2005, Jakimavicius, 2009, Guzys, 2006): irrational city facilities in communication terms and improper traffic system’s facilities; improper crossings of streets with intense traffic; absence of the main streets of high-speed continuous traffic; no passenger traffic parking lots in the largest routs; irrational usage of streets with intense traffic driving part.

In consequence of congestions there arises increasing pollution, impairment of people health, and economic loss. Every working day morning and afternoon traffic congestions are formed on the main city roads and they last one, two, sometimes even three hours. Subject to traffic intensity, crossings throughput, compatibility of traffic regulation, accidents, every car spends in congestions from some minutes to some tens of minutes. Some drivers in the congestions get into damage situations or traffic accidents, and the situation becomes heavier.

Irrational urban facilities in communication terms

Typical urban structure attributes:

- Central city part with narrow streets surrounding blocks of flats, buildings of administrative, cultural purpose – architecture monuments.
- Medium city part with broader streets, bigger blocks of flats, industrial and administrative buildings.
- Asymmetric city dwelling and industrial micro-districts formed in the last century.

Concentration of working places in the central zone of the city or in opposite sides of dwelling districts forms pulsatory flows of passengers in the morning and afternoon hours.

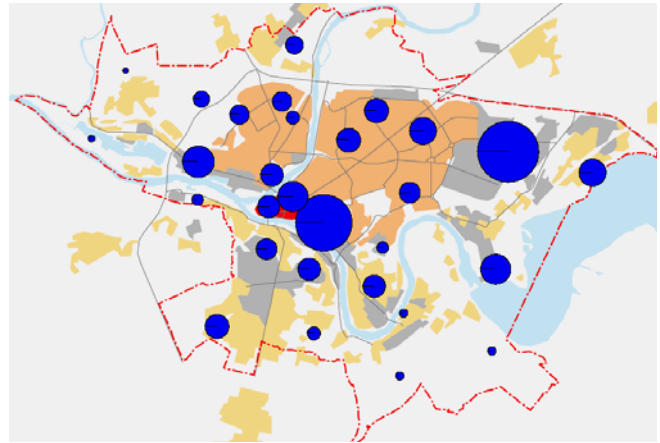


Figure 1. Zones of working places in Kaunas city (Andersson, 2006)

This statement is confirmed by traffic flows in Kaunas city investigation presented in this work, demonstrating that there exist pronounced asymmetrically located, „sleeping“ zones in the city suburbs (Silainiai, Eiguliai, Kalnieciai, Dainava), and working places are concentrated in the city centre and in the eastern city part. Therefore in the morning passengers and traffic flows move urban centre and through centre by transit to other part, and in the evening they return back.

People’s choice to live away from the city pollution, industrial and traffic noise is quite natural. To decentralize working places is not so simple, since sanitary standards do not permit building industrial plants in dwelling districts.

Irrational usage of streets with intense traffic

At present in Kaunas city there is one street (Vytauto Didžiojo Bridge) with reverse traffic lane. Reverse traffic lanes themselves effectively reduce jams on the roads and crossings. To use this lane with the lane for public traffic and mounting a public traffic lights at the crossing, allows large effect in improvement of passengers traffic.

No effective high speed public traffic service

Use of public traffic is too little because of low average driving speed, insufficient comfort of service, idle time in congestions, as well because that there are no car parking lots in the beginning of routes (park-and-ride system).

Improper facilities of traffic system

For the analysis of the facilities of the urban traffic system, facilities of streets, crossings and traffic control and traffic structure of transport, taking part in traffic, are accentuated.

In order to secure safe, rhythmical and continuous traffic, facilities of streets and crossings has to meet intensity of passengers and traffic flows. The analysis of throughput of streets and crossings demonstrated, that the throughput of streets, crossing in one-level crossings, is used just by quarter, so, conclusion should be done, that reason of traffic congestions is not an insufficient throughput of streets, but too small throughput of the crossings.

Big impact on traffic intensity and traffic congestions appearance has been done by transport structure taking part in traffic and possibility of changing it in desired direction.

Statistical traffic researches data illustrate, that using of cars with average just 1.5 of passenger is the largest (even 69%) (Andersson, 2006). At the same time amount of buses, trolleys and minibuses, in total, makes up just 13.3%, though during congestions at least on an average 50 passengers go by them.

No high-speed continuous traffic main streets

While analyzing the main streets with intense traffic, no street with continuous traffic flow was found. High-speed and continuous traffic is possible just in the streets with two-level crossings, at least, and pedestrian traffic isolated or organized perfectly. An absence of continuous high-speed traffic the main streets force drivers to choose not the best driving routes, and this increases possibility of congestions.

No motor-less traffic facilities

Bicycle transport is one of ecological traffic, as communication means, usage possibilities. Another bicycle advantage is that people have good chance to improve in health. Therefore bicycle paths should be laid not by roads, but within flat blocks away from motorcars traffic flows. Then this traffic type will be more attractive and be in service in reducing traffic congestions on roads (Wang, 2008).

After the analysis of Kaunas urban public transport routes (buses, trolleys and minibuses) and traffic flows (Figure 2), the conclusion should be stated, that the main corridors are the same – both for public traffic, and for individual - it is northern city part - centre .

The largest traffic flows in Kaunas city are at exits and entries to the centre, where streets of high throughput with large traffic intensity meet together– Savanoriu av., Jonavos st. and Karaliaus Mindaugo av., Veiverių st. Cars' flows moving by them distribute among some Senamiestis streets of smaller throughput (Sv. Gertrudos, Gimnazijos, Birstono, Saukliu st.), making jams in them (especially during peak hours).

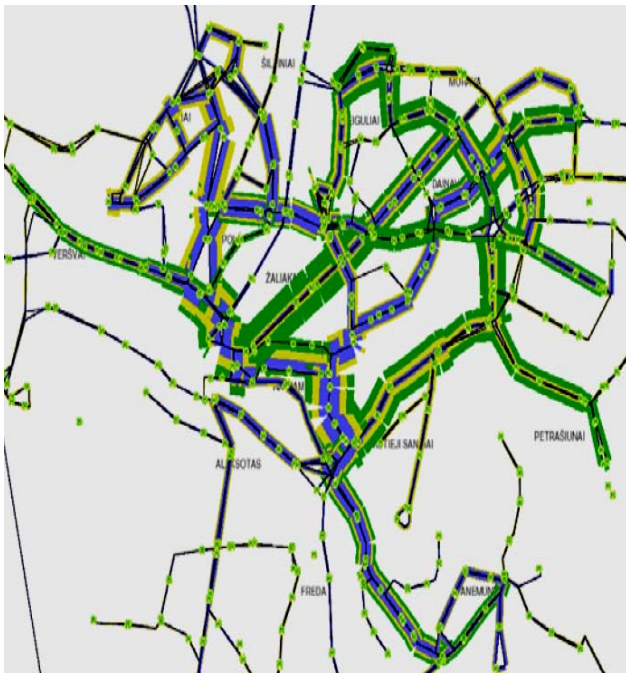


Figure 2. Scheme of Kaunas urban public transport routes and traffic flows (Andersson, 2006)

Evaluation of expenses for urban traffic congestions

The main research purpose – to determine vehicle's waste of time with flow close to system overcrowding or moving in congestion.

In order to evaluate congestions expenses and rare occasional loss many parameters and assumptions are necessary, because these parameters are expressed by physical expressions. The most important of them are (Armelius, 2005, Grant-Muller, 2007, Verhoef, 2004):

- value of travel time is used to convert time loss and/or reduced reliability and comfort into monetary units;
- speed-flow relations, describing additional vehicle impact on transport system and, herewith, expenses of other consumers and society;
- variation of demand, defining reaction of possible consumers to internalization of exterior expenses of congestions.

Expenses evaluation methods used are based on evaluation of travel time. To this end lots of investigations have been performed in various European countries (Cordis, 2000, Doll, 2002, Johansson, 1997). Actually experts are inclined to use general *VOT* values for public and goods traffic.

Marginal exterior congestions costs for concrete traffic level are calculated (Bilbao-Ubillos, 2008, Maibach, 2008, Safirova, 2007):

$$MSC_{sp}(Q) = VOT \times \frac{Q}{v^2(Q)} \times \frac{\delta v(Q)}{\delta Q}, \quad (1)$$

here MSC_{sp} - marginal exterior congestions costs; VOT - value of time (Lt./vh.h.); Q - existing traffic level (vh./h.); $v(Q)$ - function of traffic flow (km/h.).

Exterior costs are the difference between social (appearing due to usage of traffic facilities – wear of facilities, congestions, environmental pollution, traffic accidents) and internal costs (conditioned by traffic user – wear of vehicle, energy expenditure, time expenditure, transport taxes and tariffs).

Function of speed-flow depends on facilities' features, topography, weather conditions, network structure, possible travel alternatives, various traffic regulations (speed control, embark/loading procedures and so on) and driving habits.

All estimation steps depend considerably on dynamics of variation of transport system, quality of data available, and time evaluation. There are two groups in evaluation methodology (De Palma, 2005, Goodwin, 2003, Luo, 2007, Stathopoulos, 2002): congestions of narrow places, forming in road crossings and mostly prevailing in towns and settlements; congestions of flows, referring to exceeding possibilities of transit in concrete sections.

One of the main features in flows investigation is setting an average flow speed in sector, usually calculated taking into account braking at prohibitive signs and durations of standing at them, acceleration up to permitted speed, and driving at steady speed (Schneider, 2002).

Investigation of traffic flows is a complex multidimensional task, solution complication of which depends on complexity extent of a transport network. In order to analyze the particularity of forming of congestions, investigation describing in details interaction of vehicles and road facilities are necessary.

While researching traffic flows, generalization problem is encountered. Firstly, it is a problem of vehicle's individuality. Together with a driver vehicles are separate subjects with unique features, therefore in flows they depend on other vehicles, since they cannot move absolutely freely. Modern vehicles are designed to meet requirement to stand up in traffic flow, i.e. sustain normal dynamics of traffic flow.

It is rather complicated to evaluate individuality of all vehicles to investigate, therefore vehicles classification with some changes is used for research: cars, light trucks and microbuses, trucks of an average loading capacity, magistral trucks and trackers, buses.

This classification reflects particularity of vehicles moving in the city (vehicles of bigger size move slower in narrow streets), their acceleration and deceleration characteristics. Because of dynamics particularity (transportation of people), moving restrictions (required standings in stops) and impact on other vehicles, public traffic is excluded as a specific task.

Congestions of "flows" and "narrow places" are accentuated in investigation. Congestions of the first type appear, when street sector or part of traffic system is traffic-overloaded because arriving and outgoing vehicles flows are inadequate. Arriving vehicles' flow is defined by oncoming sector throughput, outgoing – by throughput of the sector itself and existing behind it one.

The throughput of a street sector is evaluated by the parameter of traffic intensity – amount of vehicles for time unit. If an average vehicle speed in a sector is known:

$$I = \frac{v}{L + k_v \cdot v}, \quad (2)$$

Here $k_v = 0.3 - 0.5$, v – speed in sector [km/h]; L – length of a car.

The main feature is an average vehicle speed in the sector, depending on facilities elements, traffic intensity, and vehicle characteristics. These parameters are associated, because, when approaching congestion making limit, cars' interaction appears. Traffic flow intensity is determined with specified averages traffic flows speeds in separate sectors, travel time and, the main thing, in defining the sector throughput. Flow particularity has been determined, as well – impact of number of lanes and evaluated wasted time with different intensity of vehicles flow. Having data on traffic flows, it is possible to determine frequency of arriving and outgoing vehicles and time intervals between them and evaluate situation in a crossing. Schemes of vehicles movement were formed, projecting arriving of vehicles one by one or by blocks, and data on flows directions and intensity collected. According to queue extent it is possible to judge about quality of traffic control system and loading of crossing with transport and forecast possible congestions.

Traffic flow is not ideal – single drivers are unable to keep the minimal permitted distance between vehicles. In four-lanes streets crossings where duration of green traffic lights signal is 30 s, with permitted speed 40 km/h in a sector, 30–34 vehicles pass a crossing. Kaunas city crossings with three-lanes streets prevailing were chosen for the investigation. Wasted time (extra time to pass a sector) in them is calculated for one maneuver to change a lane under ideal conditions (all the drivers behave especially well-wishingly) till complete restoring of flow, subject to unspoiled traffic flow speed, varies from 6.6 s, with speed 18 km/h, up to 13 s, with speed 72 km/h.

It is necessary to specify traffic circumstances when flows are approaching to a throughput limit of the traffic system sector. When a sector without any holdup is getting longer, an average speed of vehicle increases, but, while moving in a flow, additional factors appear: in long sectors vehicles start re-forming, occupying more convenient positions, drivers go at uneven speed, that is why there in long sectors an average speed has a tendency to decrease.

Traffic directions in the crossing: 1– Mackeviciaus st. – Sv. Gertrudos st., 2– Saukliu st. – Sv. Gertrudos st., 3– Birstono st. – Sv. Gertrudos st., 4 – Laisves al. – Sv. Gertrudos st. (Figure 3).

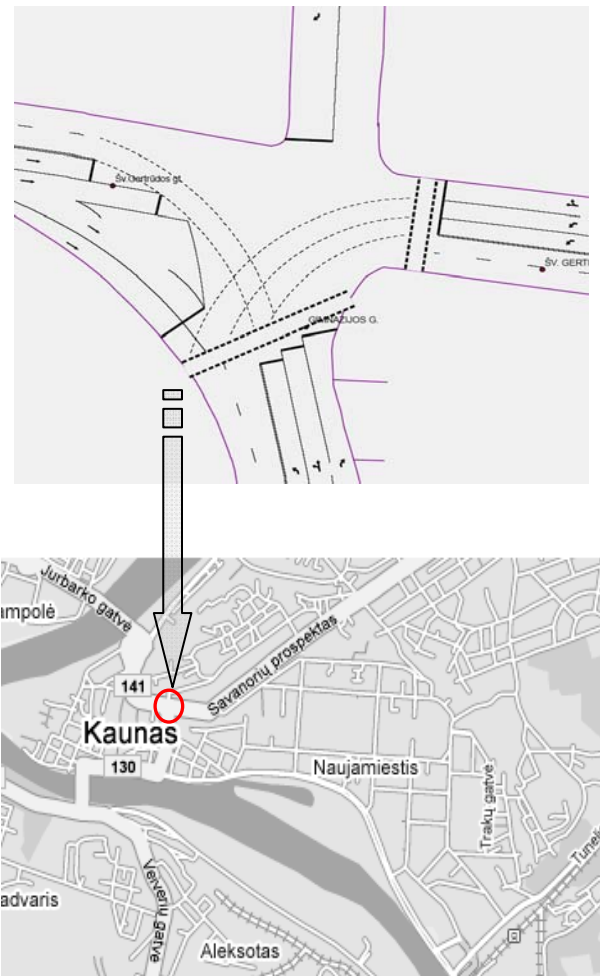


Figure 3. Investigation of traffic congestions in the crossing regulated by traffic lights

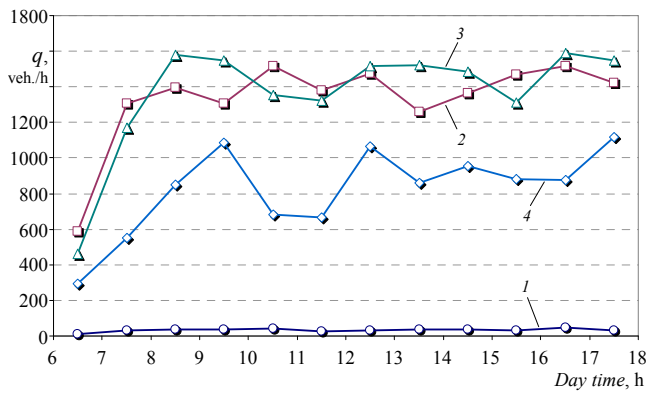


Figure 4. Amount of vehicles in the crossing Sv. Gertrudos st. – Gimnazijos st. during a day

To evaluate probability of congestions, dependencies of traffic intensity during 24 hours are used. In accordance with traffic intensity Karaliaus Mindaugo av.- Birstono st. (Figure 4) 58 vh./min for this crossing is marginal value. Congestions here formed on the average $10.5 \times 4 / 7 = 6$ h/24 h and during 24 hours $3500 \times 6 = 20000$ vehicles were involved. Large traffic intensity was found out in six (1-3,9,10,18) sectors. On the supposition, that congestions length in separate sectors proportional to flow intensity (an

average factor of six sectors is 0,838), flow unevenness during year $(1+0.8+0.7+0.6+0.4)/6=0.583$, we get, that during 24 hours $20000 \times 6 \times 0.838 \times 0.583 = 58632$ vh./24h wasted time in congestions. In 2005 in Kaunas city 21533 motorcars there were registered, 19890 of them of M1 class, 69 of M2 class, 90 of M3 class, 882 of N1 class, 206 of N2 class and 396 of N3 class. With an assumption, that cars driving in the city groups composition was similar, and one motorcar wasted in jams on the average 0.25 h, duration of time-waster is obtained.

Calculations were performed for the situation of 2010 year. In order to define congestions loss, the assumption, that traffic flows in Kaunas city increased by 5 percent every year (information of Kaunas city Transport department) was done. According to „Regitra“ registration data, there was no essential change in vehicles composition, but since 2005 every year 6 percent of cars of M1 class used fluid fuel. It is necessary to take into account additionally, that traffic intensity in the main and country roads in Kaunas city has increased by 20-30 percent and approached the flow intensity in city streets. This increases probability of congestion in cities.

Trucks in urban flows made up to 25 percent of a common traffic flow (Birstono st., Karaliaus Mindaugo av., Savanoriu av., Parodos st., Tvirtoves al., Ateities r., T. Masiulio st., Veiveriu st., Raudondvario r., Zemaiciu r.).

1 table

Expenses of traffic congestions in the crossing of Sv. Gertrudos st. – Gimnazijos st.

	Cars	Goods vehicles	Public transport	Coaches	Mikrobus		Total
					Shuttle	Other	
Wasted vehicles/day	5090	156	396	46	1068	374	7130
Wasted hours	1542	47.7	120	14.3	324	113	2161
Hour cost, Lt./h	16.73	6.5	40.92	20.5	6.5	6.5	
Waste-time cost, Lt.	25798	310	4910	293	2106	734	34151
An average amount of people in a car	1.5	1.0	40	20	8.0	1.0	
Wasted people hours	2313	47.7	4800	286	2592	113	10152
Fuel expenditures per hour, l	4.0	6.5	6.0	6.0	5.0	5.0	
Total fuel expenditures, l	6168	310	720	85.8	1620	565	9469
Total fuel expenditures, Lt.	24055	1209	2808	336	6318	2203	36929
Total congestions expenses per day in the crossing, Lt.							71080

Impact of sustainable urban traffic system development on the reduction of congestions expenses

Traffic ecological, economic ones and other problems associated with traffic can be solved just with a complex implementation of the whole group of means and radical changes of traffic facilities, which include correction of passengers' flows.

There are rather many means to solve traffic congestions issue, but they are of not equally efficient, and their realization calls for huge funds and financing

possibilities (De Palma, 2005, Greenwood, 1996, Liedtke, 2005, Van Woensel, 2009).

Additional traffic lanes

The mean possibly able to reduce delays is to arrange crossings and in them so many additional traffic lanes and of such length, that they were packed by driving transport in operation of cycle traffic lights cycle. This solution would allow avoiding congestions, increase crossings throughput, but it requires large additional areas in front of crossings, in the crossings and even larger ones after crossings. So this measure does not eliminate pulsatory traffic and could even increase risk of traffic accidents

after the crossing in a narrowed down road. That is why it is not quite attractive and impossible to realize everywhere, but very often used as partial measure of reduction of traffic congestions.

Green wave

Another more efficient measure of reduction of traffic congestions in all street crossings and crosswalks is a coordinated traffic regulation by "Green wave". This measure reduces driving time, probability of traffic accidents, pollution, if transport traffic intensity does not exceed throughput of crossings, regulated by "Green wave" (Daunoras, 2008). Unfortunately, its disadvantage is that it does not increase throughput of crossings, because this requires big initial and operational costs. In road and crossing with „Green wave” left turn would be limited, and varying traffic intensity on the road would remain – streets throughput would not be used to end. In order to achieve traffic by "Green wave" without any troubles, duration of a green signal on traffic lights in all the crossings of this road shall be set in accordance with maximum traffic flow on the road. Therefore this traffic regulation measure is usable only in those roads, throughput of which is three – five times bigger than predictable calculated maximum value of varying traffic intensity period.

Reverse traffic lane, traffic lights of public transport

In streets of intense traffic it is reasonable to arrange of reverse traffic lanes, capable to increase the amount of traffic lanes in required direction during congestion hour, secure undisturbed public traffic between crossings. An additional traffic lane and traffic lights regulating public transport traffic should secure undisturbed public transport traffic in crossings.

Crossings of different levels

The best traffic congestions prevention measure might be roads nodes of different levels in streets with intense traffic. They would secure continuous traffic flow in the roads, make possibility to use streets designed throughput completely and 3–5 times increase their actual throughput, considerably decrease probability of traffic accidents, negative impact on peoples health, driving time, pollution due to cars, fuel and time expenditures.

Now in all Lithuania cities there are no high speed public transport routes without intermediate stops and with traffic lights controlled by transmitter mounted in it.

Popularity of such traffic would grow considerably having organized high speed transit of part of public transport traffic, improved driving conditions in it, arranged parking-lots for cars and bicycles at the beginning of route. Some part of passengers of an individual transport would choose high speed public transport, and therefore traffic amount would decrease itself in congestion hours.

If at least one third of passengers using individual transport had ran away with public transport, then vehicles amount of public transport (in examined zone) would have increased just by 12–13 pc., and total amount of transport vehicles would have decreased even at 400 pc., or about 22%. Such vehicles amount in one traffic lane would extend for two and half kilometers, and by removing this amount of cars from congestions the problem would have been solved completely or by great part, at least.

City arterial streets, evaluation of their classes according to traffic intensity conformity with requirements of standard acts have to be listed exactly in the city general plan.

It is necessary to use existing facilities optimally, new and better informational and communication technologies are needed for this, the "advanced and integrated logistics system" has to be implemented, new ideas, firstly speaking about city traffic, are required. It is important to improve coordination of various transport vehicles and stimulate the choice of more ecological transport vehicles and apply technologies with less amount of exhaust and so on.

Conclusions

In order to make public service more efficient, it is centralized gradually. The distance between citizens and service conveyor is increasing. Plants, as well, follow this tendency – amount of the centers of production, storage and distribution is reduced. Activity is concentrated because of deteriorative accessibility conditions, so partially mobility is forced.

Travels and distances are conditioned by personal, political and business solutions. Cost value shall for some distance is very important. In the future a lot should be changed in this field, because stock cost will be increased (firstly of mined out fuel), exterior expenditures will be internalized, public funds for facilities will decrease and so on. But nevertheless clear political solutions on conclusions what should be done are missing. While carrying resolutions on facilities, it should be necessary to more extensively take into account stable development. It should be necessary to take into account not only the improvements of links, efficiency and less time expenditures, but related ecological and social expenditures, as well.

After the analysis of some transport flows in the city traffic analysis, the investigation of traffic congestions reasons, and conclusions could be done:

there is no methodical facilities development programme of the city streets;

roads with intense traffic crossings of the city are old-fashioned, and their throughput is by three, four times smaller than streets throughput and traffic flows intensity;

there is no high speed public traffic service created in the, what becomes a pretext to use an individual transport, and this increases traffic intensity and traffic congestions;

there are no continuous traffic roads of radial directions in the city, therefore the largest traffic congestions are city centre;

there is no reverse lanes in the streets with intense traffic, what could increase roads throughput and no public transport traffic lights before crossings, which would reduce, at least, congestions of this traffic.

Sustainable urban traffic system development reducing congestions costs shall be based on long term "sustainable people and goods mobility vision".

References

- A Sustainable Future for Transport - Towards an Integrated, Technology-Led And User-Friendly System. (2009). Publications Office of the European Union Directorate – General For Energy And Transport.
- Andersson, P. G., & Fredriksson, L. (2006). Project of Kaunas Public Transport. Trivector Traffic AB.
- Armelius, H. (2005). An Integrated Approach to Urban Road Pricing. *Journal of Transport Economics and Policy* (1), 75-92.
- Baltrenas, P., & Kazlauskienė, A. (2009). Sustainable Ecological Development Reducing Negative Effects of Road Maintenance Salts. *Technological and Economic Development of Economy* (1), 178-188.
- Button, K. J., & Hensher, D. A. (2005). Handbook of Transport Strategy, Policy and Institutions. Oxford: Elsevier Ltd.
- Bickel, P. (2006). Developing Harmonised European Approaches for Transport Costing and Project Assessment (HEATCO). Deliverable D6: Case Study Results: IER, University of Stuttgart.
- Bilbao-Ubillos, J. (2008). The Costs of Urban Congestion: Estimation of Welfare Losses Arising From Congestion on Cross-Town Link Roads. *Transportation Research A* (42), 1098-1108.
- Butkevicius, J., & Lingaitis, L. P. (2005). The Problems of Urban Public Transport and Their Solution Trends. *Proceedings of the 11th International Conference “Urban Transport XI: Urban Transport and the Environment in the 21st Century”*. Southampton: WIT Press, 85-93.
- Ciegis, R., Ramanauskienė, J., & Martinkus, B. (2009). The Concept of Sustainable Development and its Use for Sustainability Scenarios. *Inzinerine Ekonomika-Engineering Economics*(2), 28-37.
- Ciegis, R., Ramanauskienė, J., & Startienė, G. (2009). Theoretical Reasoning of the Use of Indicators and Indices for Sustainable Development Assessment. *Inzinerine Ekonomika-Engineering Economics*(3), 33-40.
- Cygas, D., Jasiuniene, V., & Bartkevicius, M. (2009). Assessment of Special Plans and Technical Designs with Regard to Traffic Safety. *Journal of Civil Engineering and Management* 15(4), 411-418.
- CORDIS. *TransPriceProject*. (2000). A European Study of Various Pricing Strategies for Reducing Urban Traffic Congestion and Air Pollution Emissions.
- Cruzado, I. (2005). Sustainable Transportation Systems. *Proceedings of the 11th International Conference “Urban Transport XI: Urban Transport and the Environment in the 21st Century”*. Southampton: WIT Press, 343-349.
- Daunoras, J., Bagdonas, V., & Gargasas, A. (2008). City Transport Monitoring and Routes Optimal Management System. *Transport* 23(2), 144-149.
- De Palma, A., Lindsey, R., & Proost, S. (2006). Research Challenges in Modelling Urban Road Pricing. *Transport Policy* (13), 149-161.
- De Palma, A., Kilani, M., & Lindsey, R. (2005). Congestion pricing on a road network: a study using the dynamic equilibrium simulator METROPOLIS. *Transportation Research A* (39), 588-611.
- Doll, C. (2002). Unification of Accounts and Marginal Costs for Transport Efficiency (UNITE). Deliverable 7: User Cost and Benefit Cost Studies Leeds: ITS.
- Ilgakojyte-Bazariene, J., Marksaitis, D., & Sapragnas, J. (2005). Estimation of the Public Transport System in Kaunas city. *Proceedings of the 11th International Conference “Urban Transport XI: Urban Transport and the Environment in the 21st Century”*. Southampton: WIT Press, 105-111.
- Jakimavicius, M., & Burinskiene, M. (2009). A Gis and Multi-Criteria-Based Analysis and Ranking of Transportation Zones of Vilnius City. *Technological and Economic Development of Economy* 15(1), 39-48.
- Johansson, O. (1997). Optimal Road Pricing: Simultaneous Treatment of Time Losses, Increased Fuel Consumption, and Emissions. *Transportation Research D* (2), 77-87.
- Goodwin, P. (2003). The Economic Cost of Congestion when Road Capacity is constrained. 6th International Symposium on Theory and Practice in Transport Economics.
- Grant-Muller, S., & Laird, J. (2007). International Literature Review of the Costs of Road Traffic Congestion. Scottish Executive.
- Greenwood, I.D., & Bennett, C. R. (1996). The Effects of Traffic Congestion on Fuel Consumption. *Road & Transport Research* (2), 18-31.
- Guzys, A., Ilgakojyte-Bazariene, J., & Sapragnas, J. (2006). Assessment of the Sustainability of the Street Network in Kaunas City. *Proceedings of the 4th International Conference “The Sustainable City IV: Urban Regeneration and Sustainability”*. Southampton: WIT Press, 631-636.
- Kazlauskaitė, R., & Buciniene, I. (2008). The Role of Human Resources and Their Management in the Establishment of Sustainable Competitive Advantage. *Inzinerine Ekonomika-Engineering Economics*(5), 78-84.
- Kilijoniene, A., Simanaviciene, Z., & Simanavicius, A. (2010). The Evaluation of Social and Economic Development of the Region. *Inzinerine Ekonomika-Engineering Economics*, 21(1), 68-79.

- Liedtke, G., Shmedding, D., & Marouda, T. (2005). Cost Benefit Analysis for Urban Policy Measures Related to Economic Transport. *Proceedings of the 11th International Conference "Urban Transport XI: Urban Transport and the Environment in the 21st Century"*. Southampton: WIT Press, 895-905.
- Litman, T. (2001). Generated Traffic: Implications for Transport Planning. *ITE Journal* (4), 38-47.
- Luo, Q., Juan, Z., Sun, B., & Jia, H. (2007). Method Research on Measuring the External Costs of Urban Traffic Congestion. *Journal of Transportation Systems Engineering and Information Technology* (5), 9-12.
- Maibach, M., Schreyer, C., & Sutter, D. (2008). Handbook on Estimation of External Cost in the Transport Sector: Produced within the study Internalization Measures and Policies for All external Cost of Transport (IMPACT). CE, Delft.
- Safirova, E., Gillingham, K., & Houde, S. (2007). Measuring Marginal Congestion Costs of Urban Transportation: Do Networks Matter? *Transportation Research Part A: Policy and Practice* (8), 734-749.
- Schneider, F., Nordmann, A., & Hinterberger, F. (2002). Road Traffic Congestion: The Extent of the Problem. *World Transport Policy & Practice* (1), 34-41.
- Startiene, G., & Remeikiene, R. (2009). The Influence of Demographical Factors on the Interaction between Entrepreneurship and Unemployment. *Inžinerine Ekonomika-Engineering Economics*(4), 60-70.
- Stathopoulos, A., & Karlaftis, M. G. (2002). Modeling Duration of Urban Traffic Congestion. *Journal of Transport Engineering* (6), 587-590.
- Van Woensel, T., & Cruz, F. R. B. (2009). A Stochastic Approach to Traffic Congestion Costs. *Computers & Operations Research*. (6), 1731-1739.
- Verhoef, E. T., & Rouwendal, J. (2004). A Behavioural Model of Traffic Congestion: Endogenizing Speed Choice, Traffic Safety and Time Losses. *Journal of Urban Economics* (3), 408-434.
- Wang, D., Feng, T., & Liang, C. (2008). Research on Bicycle Conversion Factors. *Transportation Research A* (42), 1129-1139.
- Zuidgeest, M. H. P., Van., & Maarseveen M. F. A. M. (2006). Sustainable Urban Transport Development: A Modeling Approach. *Proceedings of the 4th International Conference "The Sustainable City IV: Urban Regeneration and Sustainability"*. Southampton: WIT Press, 659-668.

Artūras Keršys

Spūsčių sąnaudas mažinanti darni miesto transporto sistemos plėtra

Santrauka

Pagrindinė Lietuvos, kaip ir visų pasaulio didmiesčių, problema – transporto spūstys, susiformuojančios dėl šių priežasčių: neracionali susisiekimo požūrių miesto ir netinkama transporto sistemos infrastruktūra; netinkamos intensyvaus eismo gatvių sankryžos; nėra greitojo nenutrūkstamo eismo magistralinių gatvių; keleivinio transporto stambiausiuose maršrutuose nėra automobilių stovėjimo aikštelių; neracionaliai išnaudojama intensyvaus eismo gatvių važiuojamoji dalis.

Transporto spūsčių padariniai: didėjanti tarša, blogėjanti žmonių sveikata, ekonominiai nuostoliai. Kiekvienos darbo dienos rytą ir popietę didmiesčių pagrindiniuose keliuose susidaro transporto spūstys ir jos užtrunka vieną, dvi, o kartais net tris valandas. Priklausomai nuo eismo intensyvumo, sankryžų pralaidumo, eismo reguliavimo suderinamumo, eismo įvykių, kiekvienas automobilis susidarius spūstims, prastovi nuo kelių iki keliasdešimties minučių. Kai kurie vairuotojai, patekę į spūstį, skubėdami sukelia avarines situacijas arba eismo įvykius, o tuo dar labiau sukomplikuoja ir taip sudėtingą situaciją.

Pagrindinis tyrimo uždavinys – transporto priemonės gaišties nustatymas judant srautui, artimam sistemos perpildymui arba spūstyje.

Spūsčių sąnaudoms bei reikiams atsitiktiniams nuostoliams įvertinti būtina daug parametų ir prielaidų, nes šie parametrai įvertinti fizikinėmis išraiškėmis. Svarbiausios iš jų:

- kelionės laiko vertė naudojama laiko nuostoliams ir(arba) sumažėjusiam patikimumui bei komfortui išversti į piniginius vienetus;
- greičio-srauto ryšiai, aprašantys papildomos transporto priemonės poveikį transporto sistemai ir kitų vartotojų bei visuomenės išlaidas;
- paklausos kitimas, apibreziantis galimą vartotojų reakciją į išorinių spūsčių sąnaudų internalizaciją.

Tyrėjų naudojamos sąnaudų įvertinimo metodikos remiasi kelionės trukmės vertinimu. Tam tikslui atlikta daugybė tyrimų įvairiose Europos šalyse. Darbe naudojamos ekspertų siūlomos apibendrintos išorinių sąnaudų reikšmės viešajam ir kroviniam transportui (skirtumas tarp socialinių reikšmių, atsirandančių dėl transporto infrastruktūros naudojimo, – infrastruktūros nusidėvėjimas, spūstys, aplinkos tarša, eismo įvykiai), ir vidinių sąnaudų, sąlygojamų transporto naudotojo, reikšmės – transporto priemonės nusidėvėjimas, energijos sąnaudos, laiko sąnaudos, transporto mokesčiai ir tarifai.

Visi vertinimo veiksmai labai priklauso nuo transporto sistemos kitimo dinamikos ir turimų duomenų kokybės bei laiko įvertinimo. Sąnaudų įvertinimo metodikoje skiriamos dvi grupės:

- siaurų vietų spūstys, susidarantys kelių sankirtose ir labiausiai paplitusios miestuose bei gyvenvietėse;
- srautų spūstys, rodančios, kad pervežimo galimybės konkrečiuose atkarpose viršytos.

Eismo srautų tyrimas yra kompleksinė daugiamačė problema, kurios sprendimo sudėtingumas priklauso nuo transporto tinklo sudėtingumo laipsnio. Spūsčių susidarymo specifikai analizuoti, būtini tyrimai, detalios aprašantys transporto priemonių ir kelio infrastruktūros bei transporto priemonių tarpusavio sąveiką. Tyrime išskirtos „srautų“ ir „siaurų vietų“ spūstys. Pirmojo tipo spūstys susidaro, kai gatvės ruožas ar transporto sistemos dalis perkraunama transportu dėl to, kad neatitinka atvykstančių ir išvykstančių transporto priemonių srautai. Atvykstančių transporto priemonių srautą apibrėžia prieš tai esančio ruožo pralaidumas, išvykstančių – paties ruožo ir už jo esančio ruožo pralaidumai.

Tyrimui pasirinktos Kauno miesto sankryžos gatvių ruožuose dominuoja trijų eismo juostų gatvės. Laiko gaištis (laiko priedas ruožui įveikti) jose, apskaičiuota vienam juostos keitimui manevrui idealiomis sąlygomis (visi vairuotojai elgiasi ypač geranoriškai) iki visiško srauto atkūrimo, priklausomai nuo nepažeisto eismo srauto greičio, kinta nuo 6.6 s, esant 18 km/val. greičiui, iki 13 s, esant 72 km/val. greičiui. Gatvės ruožo pralaidumas įvertintas eismo intensyvumo parametru – transporto priemonių skaičiumi laiko vienetai. Spūsčių tikimybei įvertinti panaudotos eismo intensyvumo kitimo para

priklausomybės. Sprendžiant pagal eismo intensyvumą Karaliaus Mindaugo pr. – Birštono g. 58 aut./min. šiai sankryžai yra ribinis dydis. Spūstys čia susidarydavo vidutiniškai $10.5 \times 4/7 = 6$ val./parai ir buvo susijusios su per parą paliesdavo $3500 \times 6 = 20000$ transporto priemonių.

Transporto eismo ir su juo susijusias ekologines, ekonomines problemas įmanoma išspręsti tik kompleksiskai įgyvendinant visą aibę priemonių ir radikalčiai keičiant eismo infrastruktūrą, kuri apima keleivių srautų koregavimą.

Yra gana daug priemonių transporto spūstų problemai išspręsti, tačiau jos nevienodai veiksmingos, o jas įgyvendinti trukdo didžiulės lėšos ir finansavimo galimybės.

Viena iš priemonių, kurią naudojant būtų galima sumažinti prastovas, – prieš sankryžas ir sankryžose nutiesti tiek papildomų eismo juostų ir tokio ilgio, kurias užpildytų keliu važiuojantis transportas per šviesoforo darbo ciklo laiką. Taip būtų galima išvengti spūstų, padidintų sankryžų pralaidumą. Tačiau šiai priemonei įgyvendinti reikia didelių papildomų plotų prieš sankryžas, pačiose sankryžose ir dar didesnių už sankryžų. Ši priemonė nepanaikina pulsuojančio eismo ir gali padidinti eismo įvykių pavojų už sankryžos susiaurėjus keliui. Dėl to ji nėra itin patraukli ir ne visur įmanoma įgyvendinti, tačiau labai dažnai naudojama kaip dalinė transporto spūstų mažinimo priemonė.

Kita veiksmingesnė spūstų sumažinimo priemonė visose gatvės sankryžose ir pėsčiųjų perėjose – koordinuotas eismo reguliavimas „žaliąja banga“. Ši priemonė sumažina važiavimo trukmę, eismo įvykių tikimybę, taršą, jeigu transporto eismo intensyvumas neviršija sankryžų, reguliuojamų „žaliąja banga“ pralaidumo. Deja, šios priemonės trūkumai yra tai, kad ji nedidina sankryžų pralaidumo, nes tam reikalingos didelės pradinės ir eksploatacinės investicijos. „žaliosios bangos“ kelyje ir sankryžose būtų ribojamas kairysis posūkis, o kelyje išliktų kintantis eismo intensyvumas – nebūtų iki galo išnaudojamas gatvių pralaidumas. Kad eismas „žaliąja banga“ vyktų be sutrikimų, visose to kelio sankryžose šviesoforų žalio signalo trukmė turi būti nustatyta pagal didžiausią transporto srautą kelyje. Todėl ši eismo reguliavimo priemonė tinkama naudoti tik tuose keliuose, kurių pralaidumas yra tris – penkis kartus didesnis už prognozuojamo kintančio eismo intensyvumo periodo skaičiuojamą didžiausią reikšmę.

Intensyvaus eismo gatvėse racionalu įrengti reversinio eismo juostas, dėl kurių galėtų padaugėti kurios galėtų padidinti eismo juostų skaičius reikiama kryptimi spūsties valandą, taip pat galėtų būti užtikrinamos viešojo transporto netrukdomas eismas tarp sankryžų. Sankryžose netrukdomą viešojo transporto eismą turėtų užtikrinti papildoma eismo juosta ir viešojo transporto eismą reguliuojantis šviesoforas.

Bene geriausia transporto spūstų prevencijos priemonė – skirtingų lygių kelių mazgai intensyvaus eismo gatvėse. Jie užtikrintų nepertraukiamą transporto srautą keliuose, sudarytų galimybę iki galo išnaudoti gatvių projekcinį pralaidumą ir 3–5 kartus padidinti faktinį jų pralaidumą, gerokai sumažintų eismo įvykių tikimybę, neigiamą poveikį žmonių sveikatai, važiavimo trukmę, automobilių taršą, degalų ir laiko sąnaudas.

Šiuo metu visuose Lietuvos didmiesčiuose nėra nei vieno greitojo viešojo transporto maršruto, kuriame nebūtų tarpinių stotelių, o sankryžų šviesoforai būtų valdomi jame sumontuotu siūstuvu. Organizavus greitąjį tranzitinį dalies viešojo transporto eismą, pagerinus jame važiavimo sąlygas, maršruto pradžioje įrengus lengvųjų automobilių ir dviračių stovėjimo aikšteles, tokio transporto populiarumas gerokai padidėtų. Nemaža dalis individualaus transporto keleivių pasirinktų greitąjį viešąjį transportą, o dėl to savaime sumažėtų transporto kiekis spūsties valandomis.

Jeigu bent trečdalį individualiu transportu besinaudojančių keleivių pavyktų suvilioti naudotis viešuoju transportu, tai viešojo transporto priemonių skaičius (nagrinėjamoje zonoje) padaugėtų tik 12–13 vnt., o bendrai transporto priemonių skaičius sumažėtų net apie 400 vnt., arba apie 22 %. Toks automobilių skaičius vienoje eismo juostoje nusidriektų per pusrčio kilometro, o pašalinus tiek automobilių iš spūsties problema būtų išspręsta visiškai arba bent iš dalies.

Miesto bendrajame plane turi būti tiksliai įvardytos miesto arterinės gatvės, jų kategorijos pagal eismo intensyvumą atitikties norminių aktų reikalavimams vertinimas.

Būtina optimaliai naudoti esamą infrastruktūrą. Tam reikalingos naujos ir geresnės informacinės ir ryšių technologijos, turi būti įdiegta „pažangi ir integruota logistikos sistema“, reikalingos naujos idėjos, visų pirma kalbant apie miesto transportą, reikia gerinti įvairių transporto priemonių derinimą ir skatinti rinktis ekologiškesnes transporto priemones bei taikyti mažesni išlākų kiekį išskiriančias technologijas ir kt.

Raktažodžiai: miesto transportas, darni plėtra, eismo spūstys, išorės sąnaudos.

The article has been reviewed.

Received in August, 2010; accepted in February, 2011.