



TRAFFIC RESTRICTION POLICIES IN LITHUANIAN CITIES BASED ON VILNIUS CASE STUDY

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Abstract. The paper presents the results of a feasibility study on traffic restriction strategies in the Old Town of Vilnius, Lithuania. The annual growth of traffic flows in the narrow streets of Vilnius Old Town is increasing environmental, traffic safety, economic and social problems. The article includes an analysis of worldwide land use and transport strategies, surveys of the traffic flows in Vilnius Old Town and the analysis of survey results. As a follow-up to the afore-mentioned research, the article presents strategic proposals related to traffic organization and the substantiation of the made proposals. In addition, the article includes more widely analyzed strategic proposals of the Old Town by-passes, loop and paid entrances to the Old Town section.

Keywords: Vilnius Old Town, transport and land use strategies, transit traffic, traffic organization, traffic restrictions, road pricing.

1. Introduction

The growth of traffic flows in larger Lithuanian cities has become a difficult dilemma (Viteikienė, Zavadskas 2007). Social and economic sustainability in these cities is closely related to the character of their communication system, and today requires decisions on which means of communication should be given priority and which model (American or European) should the traffic organization solutions be based on.

The aim of this article is to complete an analysis of traffic restriction and the organization possibilities in the Lithuanian cities as well as to provide strategic proposals on how to improve the existing traffic situation. With this aim in mind the article describes several worldwide traffic restrictions and organization measures, traffic flow surveys and includes an analysis of the survey results. Finally, the article presents proposals related to traffic organization and a substantiation of these proposals.

2. Current situation

The annual growth of traffic flows in Vilnius Old Town has increased problems of the environment, traffic safety, economic and social issues (Flay *et al.* 2007; Juškevičius, Burinskienė 2007; Orru *et al.* 2008). The Old Town has been included into the UNESCO World Heritage List and it is a sensitive zone of the city from the transportation point of view, because it is located in a hollow, the prevailing streets are narrow and poorly aerated and the traffic is very inten-

sive. Vehicle-generated noise in the city centre causes a negative impact on the working capacity of the centre residents and their health and rest at night due to the frequently exceeded permissible noise levels in the Old Town streets.

The most problematic core of Old Town covers 92 ha of the central part of Vilnius city. Based on expert and statistical forecasts, it has been shown that car ownership in Vilnius in 2020 will make-up approx 600 cars per 1000 inhabitants (Grigonis 2005). Due to the specific transportation system and such a large number of cars in the city, the transport infrastructure will be inevitably become oversaturated and traffic conditions in the Old Town will become more problematic and more difficult each year.

The transport system research carried out by us, the comprehensive statistics and the monitoring analysis enable us to define the basic problems related to transport and traffic in the central parts of Kaunas and Klaipėda, namely: the central street network is not properly designed for the current peak hour transport flows; unreliable transport system and insufficient traffic safety; lack of spaces for parking (in particular short-term parking) in the centre, as most vehicles are parked for 5–8 h; vehicles parked close to intersections, on the sidewalks and on the streets (carelessly and in restricted areas) impede normal and safe traffic of transport, pedestrians and tourists; transport generated noise and pollution have negative impact on residential and historical environment; and the public transport is not able to compete with cars.

The traffic restriction means to be implemented in the old town of Vilnius could be successfully applied in Kaunas and Klaipėda. An integrated car parking system should be developed as an important infrastructure element of those towns that ensures a sustainable development of the central parts of towns. It is also necessary to protect and foster cultural and historical environment of the old towns of Kaunas and Klaipėda by giving priority to pedestrians and tourists.

The main means for traffic restriction in the central parts of Kaunas and Klaipėda are the following: reduction of transit transport flows; introduction of priority pedestrian streets; reduction of the number of parking spaces on the streets and squares of the old town (differentiated parking price); differentiation of the existing street network; formation of the network of roundabouts and distribution streets of the centre and the old town; restriction of parking on the streets with the carriageway narrower than 5.0 m; modernization of the urban public transport by making corrections in the route network and granting priority traffic conditions; reserve parking spaces for the transport of the disabled (4% of the total spaces); making available the necessary number of parking spaces at newly built or reconstructed objects in accordance with the requirements.

The proposed transport mode of the central part of Kaunas is the area of calm traffic. The implementation of the bypass of the old town and the central part in the south would result in lower traffic on Birštono–Gimnazijos and Gertrūdos–Šauklių streets to 1000 vph (vehicles per hour). It is foreseen that these streets will be serviced by the priority public transport traffic. It is planned that other streets will be available only to the transport of local residents.

The main traffic restriction means in the old town of Kaunas: traffic regulations in individual zones; installation of parking facilities outside the old town; and construction of the pedestrian bridge near the Kaunas Castle.

In the perspective, the growth of the car ownership level in Kaunas and Klaipėda will be slower compared with the present growth, as it approaches the limit of relative saturation. Taking into consideration the rate of the socio-economic development of Lithuania and the forecasted 10 years, the car ownership level will not exceed 600 veh./1000 population.

Therefore the growth of transport flows in the central parts of Kaunas and Klaipėda will depend on the factors, the main of which are the following: the existing and perspective capacity of individual streets; natural transport flow growth resulting from the expansion of the car ownership level, comfort and attractiveness of car use; changes in the objects of work, residence and service; increasing density of building development; variable traffic organization and traffic regulation means, contributing to the increased network capacity.

Research carried out in the central part and the old town of Klaipėda reveals that the average number of vehicles parked simultaneously is about 4700. On weekdays the number of parked vehicles fluctuates by $\pm 7\%$. The number of vehicles parked in the central part of the town amounts to 3700, in the old town it amounts to 1000 vehicles, or respec-

tively 79% and 21%. The passenger cars account for more than 94%. The main parking areas include carriageways and yards – for more than 85% of parking spaces.

In the centre of Klaipėda more than 60% of parking spaces are occupied for 11 h, while in the old town for 9 h. It is forecasted that the rate of the growth of the need for parking places in the central parts of Kaunas and Klaipėda will be higher than the average annual growth rate of the street flows and lower than the average annual growth rate of the car ownership. With the annual car ownership growth level of 5%, the need for parking spaces will grow by 2–2.5% per year.

The parking system in the centre and the old town of Klaipėda would consist of the following elements: requirements and norms of parking infrastructure; parking facilities operated by private or other entities (paid parking, parking in yards, parking in individual buildings); public parking facilities operated by municipal entities, the parking regime that could consist of 3 zones, namely: the Red Old Town Zone with the limited vehicle traffic and parking; the Brown Centre Zone, in which parking would be partly limited; and the Green Centre Zone, in which parking would be essentially free-of-charge, with the exception of local special events.

The linear structure of Klaipėda street network that contributes to larger transport flow concentration and that average density of the street network fail to create favourable conditions for the citizens to free use of their vehicles and to avoid transport problems in the town centre. A low density of citizens of Klaipėda also aggravates transport communication and generates an extra need for transport. Transport infrastructure in the central part of Klaipėda is not capable of managing vehicle flows in peak hours. Therefore, in the central part and the old town, the public transport should be given priority, and in future it could be the only means for passenger transport. Everyday, the feasibility of parking areas in the town central part becomes an increasing problem solution of which could lie in the improvement of vehicle traffic organisation by improving technical parameters of the street network and by reducing their vehicle-generated load.

The street network of the old town of Kaunas is irregular, the street width is 6 to 12.0 m, and this results in the concentration of large transport flows (Šauklių street – 3350 vph, šv. Gertrūdos street – 3200 vph, Birštono street – 2990 vph, Gimnazijos street – 2710 vph), which cause extensive pollution as the old town is located in the bottom of two rivers and its building development is of perimeter shape. The corridor of Šauklių–šv. Gertrūdos–Gimnazijos streets is over-saturated all day long and it drastically divides the old town into 2 parts and exerts a negative impact on it. The load on the network of streets is heaviest in the central part that concentrates work, commercial and public objects, and street routes are most favourable for getting to the functionally polarised areas. Everyday, the central part of Kaunas is visited by 90–100 thousand people who come by the public transport, cars or on foot. Everyday 8000–8500 vehicles are parked in the central part of the town, including 2500 vehicles in paid parking spaces.

In the short run, the centre and the old town of Kaunas should be subject to traffic regulation.

3. Worldwide experiences

The official transport policy of the European Union (EU) and the results of the public debates on the transport policy are expressed in 3 ways, namely: the Green Paper, the White Paper, and the EU legislation. The European Union formulates and implements the transport strategy aiming at the promotion of a more sustainable mobility in towns. To that end, the following has been foreseen:

- to promote people’s interest in the energy efficient vehicles and new progressive low-emission technologies;
- to promote use of the public and engineless vehicles;
- to make special plans of parking facilities and to restrict entrance to the centre of the town;
- to develop information systems of traffic management;
- to integrate cargo and passenger transport modes;
- to develop the new transport pricing system (e.g. subsidies to the public transport from the charges collected for entrance to and parking in the central part of the town);
- to integrate planning of land use and transport with a view of reducing the need for travelling and expanding the share of travelling by the public transport;
- to encourage the people who are not keen travellers to use the public transport;
- to promote and support cycling;
- to promote telework.

A person who is driving his/her car in peak hours often pay only part of the costs, i.e. account is not taken of the external transport costs of such driving. The external transport costs consist of the following:

- traffic jams,
- harm to infrastructure,
- noise,
- traffic accidents,
- exhaust emissions.

Various ways and means have been studied and implemented all over the world so as to change the transport needs of inhabitants, to modal distribution between transport modes and to reduce environmental pollution. The two main groups of strategies used for these purposes can be mainly distinguished: land use strategy and transport strategy. The character of using these strategies is divided into technological, social, political and economic (administrative) subgroups.

Land use and transport strategies cover the planning of transport infrastructure and transport services, control, pricing and the rendering of information. The aim of a land use strategy is related to the reduction of the travel need (e.g. the concept of a sustainable and compact city). However, the implementation of transport strategies is mainly aimed at harmonizing the communication system as much as possible (e.g. charging money sums in order to reduce traffic flows, increasing the efficiency and occupation of vehicles).

Implementation of a land use strategy helps reducing travel length and time, contributing to changes in human behaviour and adds to an efficient use of the transport infrastructure. When implementing the transport strategy a modal distribution, human behaviour in selecting the travel mode and the living place is changed, the transport infrastructure is used more efficiently. From a long-term point of view the above-mentioned different strategies and their realization measures interact; therefore, they must be well coordinated (Bertolini *et al.* 2005; Shepherd *et al.* 2006).

The general objective of the PRIMA project financed by European Commission in 2000 was to analyze the reasons behind the acceptance/non-acceptance of urban road pricing schemes and to find measures to increase its acceptability. The results from a survey conducted in 8 cities, including Oslo, Stockholm, Rotterdam, Lyon, Barcelona, Berne and Zurich, resulted in the following where the participants were asked how congestion should be managed. Fig. 1 shows the results of the survey. Restrictions in city centres are not very favourable option, however 55% of inhabitants agree with such strategy.

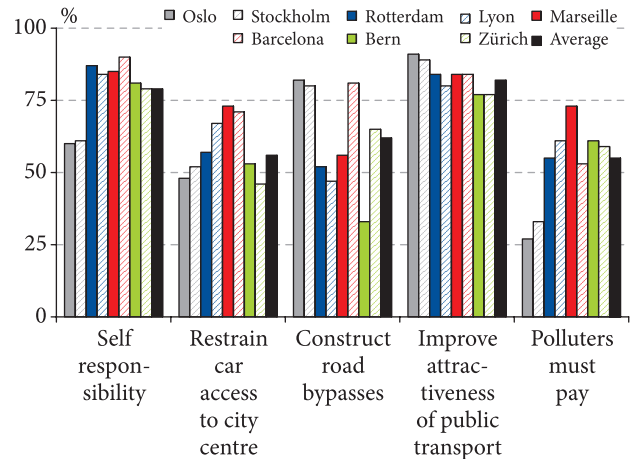


Fig. 1. How to cope with congestion and environmental nuisances (in % or “I fully agree” and “I rather agree” answers)

Inhabitants were also asked their opinion about the potential for using road pricing as a means of traffic congestion (Fig. 2).

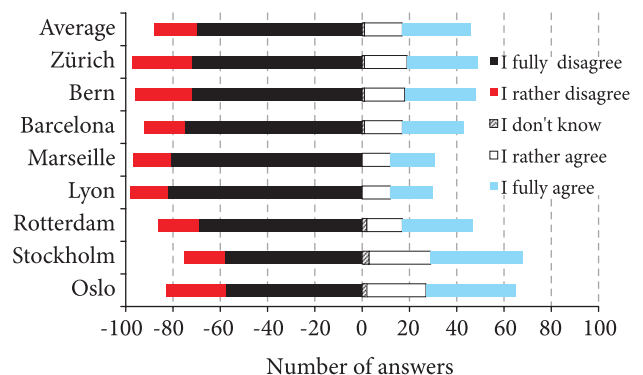


Fig. 2. View on road pricing to reduce traffic congestion and nuisances in the city

On 17 Feb, 2003 a new pricing system was introduced in London under the responsibility of Transport for London. Although before the introduction of the project the opinion was negative, after the projects had been implemented the surveys revealed that the major part of citizens approves such a step.

Experience of such cities as London, Stockholm, Oslo, Singapore, Riga and Tallinn shows that the most efficient way of traffic flow management is road pricing. Stricter traffic restrictions with the help of prohibiting signs is not as attractive as road pricing, because for a certain time the traffic is limited to all the users, and the number of violators increases making these strategies non-beneficial to the businesses located in the Old Town. On the other hand, Vilnius Old Town is large and it would be unwise to leave the central part of the city without transport communication (Hensher, Puckett 2007; Paliulis, Valeika 2005; Rye *et al.* 2005).

4. Traffic survey in Vilnius Old Town

Complex traffic surveys in Vilnius Old Town of City were carried out on Thursday 29 Sept, 2005 and Saturday 22 Oct, 2005. The students from Vilnius Gediminas Technical University, in the Dept of Urban Engineering completed surveys of traffic flows on 7 main entrance streets to the Old Town. A major part of the day's traffic and pedestrian flows were surveyed as well as the occupancy of parking places in Vokiečių Street (a central street in the Old Town). With the help of the police, the students questioned drivers on 5 main entrance streets to the Old Town (Fig. 3).

For the purpose of transport planning (Kapski *et al.* 2008) the Vilnius is divided into a finite set of transportation regions (Fig. 3), which during the student's surveys was included and used for determining the transit flows of the Old Town (transit flow – vehicles and their drivers that passed through the Old Town with a destination related to another transportation region of the city).

The questioning was carried out on 29 Sept, 6 Oct and 13 Oct in 2005 between 8:00 and 13:00. In the course of a questioning $n = 889$ questionnaires (Table 1) were collected and then processed by a database of streets and transportation regions. Since no data was available before the survey to exactly define the extent of questioning, survey errors were determined by the following formula for defining the sample size:

$$n = \frac{N \times 1.96^2 \times p \times q}{\epsilon^2 \times (N - 1) + 1.96^2 \times p \times q} \quad (1)$$

Accuracy of the survey was estimated by applying the following formula:

$$\epsilon = \sqrt{\frac{N \times 1.96^2 \times p \times q - n \times 1.96^2 \times p \times q}{n(N - 1)}} \quad (2)$$

where N – population size, the value 1.96 corresponds to 95% of probability level of the standardized normal distribution; p – anticipated probability of the event's outcome, i. e. a probability that the considered feature will occur in the considered population (usually a probability

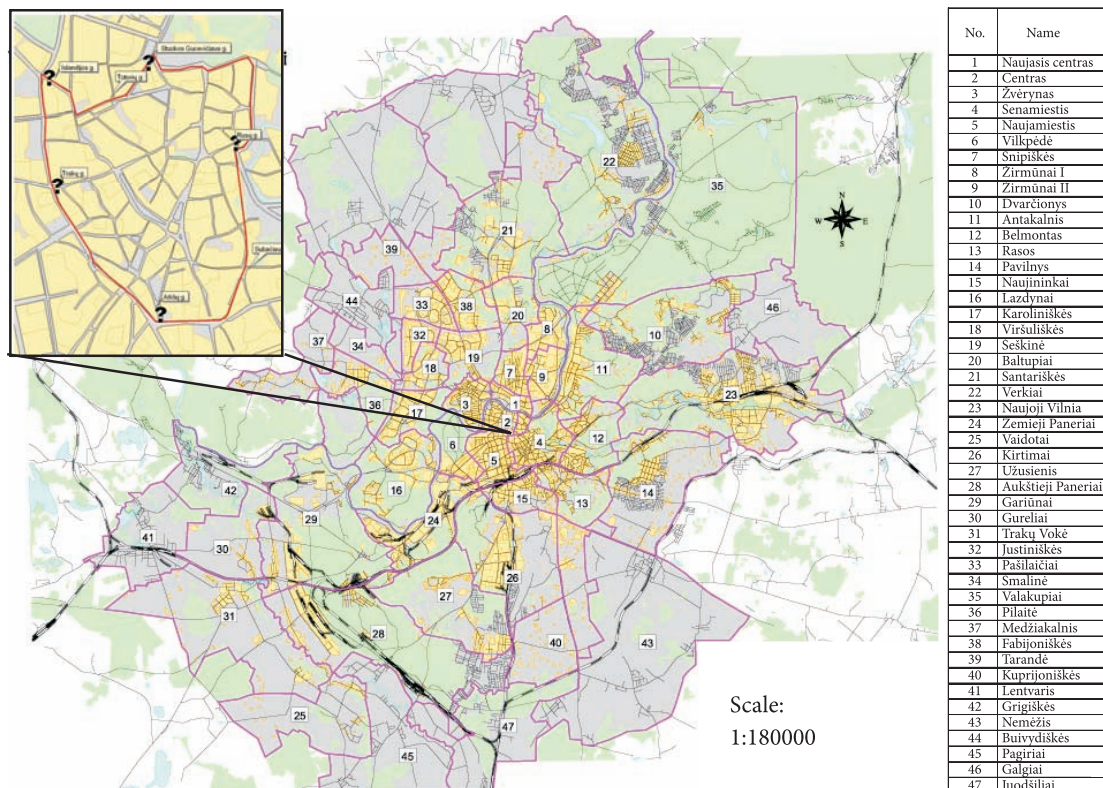


Fig. 3. Transportation regions of Vilnius City and main entrances to Old Town (questioning sites marked by ?)

of the worst variant is taken – the feature characteristic to half, i. e. 50% of the population and the selected $p = 0.5$); q – probability that the considered feature will not occur in the considered population ($q = 1 - p = 0.5$); ε – desired accuracy, usually set as 0.05.

Table 1. Traffic flow on main entrances to Old Town and number of respondents

Name of intersection	Traffic flow between 8.00 and 13.00 h	Number of respondents
Pylimo–Islandijos	3347	218
Pylimo–Trakų	2653	111
Pylimo–Arklių	1863	207
Maironio–Rusų	4042	198
Šventaragio–S. Gucevičiaus	3063	155
Total	14 968	889

Having estimated for a given number of questionnaires the accuracy with 95% probability it can be stated that the features of the questioning results have $\varepsilon = \pm 3.2$ (%) reliability. The reliability is better than the mean reliability set at the beginning of the survey.

5. Results of the traffic surveys in Vilnius Old Town

Most cars entering Vilnius Old Town were driven by males (73%) and almost 63% of the respondents attributed to the group of younger people, thus suggesting that the major part of respondents are working people. The average car occupation determined during the survey was found to be 1.35 persons.

One of the tasks of the survey in Vilnius Old Town was to determine transit flows and their indicators. The research of transport flows indicates 3 peaks during the day (Fig. 4). Evening peak is the most apparent and related to attractiveness of Vilnius Old Town.

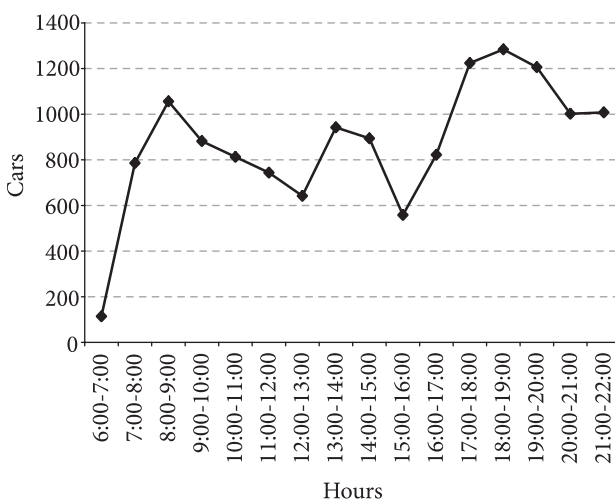


Fig. 4. Dynamics of transport flows in Vokiečių street, Vilnius Old Town

On the basis of transportation regions it was determined that about 19% of the respondents declared Vilnius Old Town as their departure and arrival point. This means that the car is used by a large number of drivers as a communication means for shorter trips to the Old Town. Such a hypothesis is confirmed by the average travel time from the departure time indicated by the drivers. Approx 44% of the drivers entering the Old Town indicated that their travel duration was up to 15 min long.

Transit traffic in Vilnius Old Town makes up 39% of the total number of passing vehicles (Fig. 5). Transit vehicles are those crossing the Old Town without making a stop and where the drivers have no travel purposes within this area.

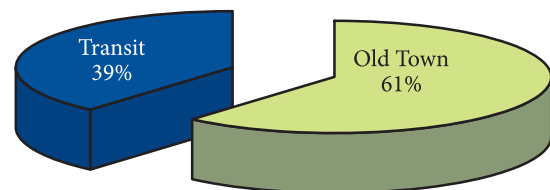


Fig. 5. Transit traffic in Vilnius Old Town

Most drivers (60%) passing through the Old Town in the day-time have job-related purposes and only a few of remaining pass through the Old Town with daily affairs or to do shopping (6% and 1%, respectively). A relatively large number of drivers (20%) indicated other travel purposes that could be related to daily or cultural travels (to take a walk, attend meetings, sport events, and/or visit medical institutions, etc. Fig. 6).

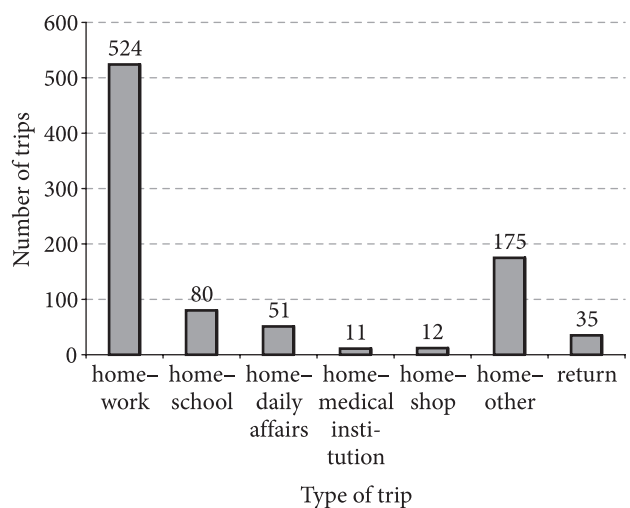


Fig. 6. Travel purposes of people crossing or entering Vilnius Old Town

Similar results were obtained after having made an analysis of the travel purposes of those who come to the Old Town. Approx 59% of travels were related to these people's job, 10% went to educational institutions and 18% had other purposes. Also, only a few people went into the

Old Town for daily affairs or to do some shopping, i.e. 6% and 1%, respectively.

Since job-related travels prevail, 68% of respondents indicated that this is their usual travel which is repeated 4.92 times per week on average. The remaining travels are made non-periodically.

To find out the drivers' attitude towards road pricing the following question was given: Is it necessary to introduce a money charge for entrance into Vilnius Old Town in order to reduce the transit traffic? Approx 66% of respondents were against charging a money sum and 34% expressed their approval. All respondents without exception that returned home to the Old Town (residents of the Old Town, $N = 13$) expressed their willingness to charge a road price for entrance into the Old Town.

Table 2. Dynamics of traffic in Vilnius Old Town per average hour (1988–2005)

Name of the entrance	1988	1995	1997	1999	2000	2002	2003	2005
Islandijos	228	300	566	688	463	744	565	653
Trakų	546	360	674	724	804	456	630	788
Arklių	166	107	84	136	104	120	210	109
Subačiaus	293	140	206	228	143	400	210	375
Latako	123	300	227	290	435	624	515	462
S. Gucevičiaus	53	50	361	240	450	282	354	267
Universiteto	–	–	–	78	100	110	120	140
Total of the entrances	1409	1157	2118	2382	2499	2736	2604	2794

Note: In 1995 entrance into the Old Town was charged and thus the traffic flows decreased at that time. Later, the charging was cancelled.

Traffic organization in the core of Vilnius Old Town is specific: some streets have speed and traffic restrictions or the traffic of heavy vehicles is prohibited. Pedestrian streets are only formal, since they are used by traffic, and parking of vehicles is allowed. Due to the fast development of the city core, the traffic flows have been continuously increasing and in the last 20 years the annual increase of the traffic flows has reached 5.5%. Table 2 presents the dynamics of traffic on the main entrances to the Old Town per an average hour in 1988–2005.

If the present general tendencies of 7% annual growth of car ownership in Vilnius will remain, then in the year 2020 Vilnius will have more than 600 cars per 1000 inhabitants (Grigonis 2005) (Fig. 7). The main statistical estimates of the model are the following: the mean absolute error is 13.38; the mean square error is 268.42; the mean error is 5.45697×10^{-12} .

The surveys and recalculations showed that Vilnius Old Town is entered by more than 63 000 cars daily at the main entrances. Transit traffic makes-up more than 25 000 vpd (vehicles per day) and this has a negative impact on the tourist and recreational attractiveness of the Old Town.

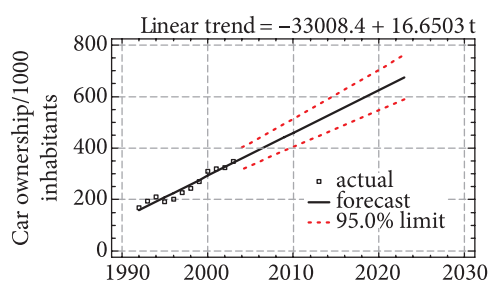


Fig. 7. The forecast of car ownership level in Vilnius (veh./1000 population)

6. Alternatives for reducing traffic volume

With the annual increase in the car ownership and traffic flows by 7% and 5.5%, respectively, it is necessary to seek for an acceptable solution to decrease traffic flows in Vilnius Old Town.

A complete prohibition of traffic (with the help of prohibitive signs) would be unacceptable with respect to the business people and the residents of Vilnius. Therefore, the more widely analyzed alternatives that can solve traffic problems are the introduction of Old Town by-passes, loop or charged entrances (the charge does not apply to emergency services, special transport, disabled people, or public transport). Encouragement of the use of public transport and non-motorized vehicles as well as walking could be analyzed as additional measures of the already-mentioned alternatives.

6.1. Alternative of the Old Town by-passes

The alternative of by-passes was analyzed by using the VIDAS (Vilnius Integrated Development Assessment System) database that was developed on the basis of EMME/2 Traffic Flow Modelling Software. When modelling traffic flows the following elements were defined: hypothetical alternation of land use (based on the Master Plan), transport system development and the growth of the car ownership levels (Grigonis, Paliulis 2007). The scenarios were developed by logically arranging the order of probable events and were based on an analysis of the existing situation and the mentioned surveys before the forecast was made. When developing the scenarios, 2 main and separate infrastructure elements were distinguished as having an influence on the traffic flows of the Old Town, i.e. the southern by-pass of the Old Town and the southern by-pass of the city.

The modelling results showed that the southern by-pass of the Old Town and the southern by-pass of the city will have an influence on the traffic flows in the territory of the Old Town. Shortly after implementation of the by-passes the traffic flows would be reduced by approx 400 cars/h, while in 2015 as many as 554 vph would by-pass the Old Town as compared to the “Do nothing” scenario. However, the general tendency of the growth of traffic flows would remain at 6.1% per year and this would allow planners to state that development of by-pass infrastructure would only slightly contribute to a sustainable development of Vilnius Old Town. On the other hand, the

realization of the by-passes provides the possibility to divert a major part of traffic flows from the narrow streets of the Old Town (at present it is necessary to cross the Old Town as there are no alternatives) and to designate narrow streets for pedestrians, bicyclists and public transport.

6.2. Alternative of the loop entrance

The idea of a loop-type entrance to Vilnius Old Town was suggested 10 years ago with the aim of reducing transport problems and increasing tourist attractiveness to Vilnius Old Town. One of the analyzed alternatives is shown in Fig. 8.

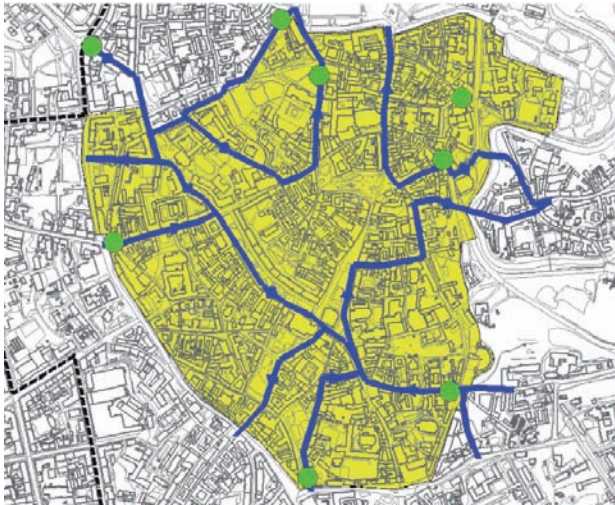


Fig. 8. Scheme of loop entrance to the Old Town

The main point of the loop entrance is to locate the loop entrances to the Old Town in a way so that the driver would previously decide where he/she is going and additional driving in the Old Town would be especially unattractive (a more simple decision would be walking). Also, unfavourable conditions are created for the transit traffic, because there is no possibility to make a straight crossing of the whole territory of the Old Town. This alternative in a short-term perspective has certain advantages as no charges will be introduced to the residents of the Old Town, and the traffic loading in the core of the Old Town will be reduced. To find out the likely influence of this traffic organization scheme a modelling of traffic flows was carried out for the years 2005 and 2015.

Changes that would occur after implementing this traffic organization scheme in 2005 are described in Scenario 2403 (the current land use and the current level of car ownership) (Table 3). Forecasting the future situation in 2015, Scenario 2404 has been developed (if the growth of the car ownership level in 2025 reaches 550 veh./1000 population, places of work and residence change under the comprehensive plan the loop entrance traffic organization system would be introduced). Comparison of Scenario 2403 and 2404 reveals that by 2015 the average annual increase of transport flows in the old town would amount to 5.9%. Compared to the existing situation, the flows on the

streets of the town would decrease by 10.9% and such relative trend would prevail until 2015.

Table 3. Transport flows on the main entrance to the old town of Vilnius after the introduction of the loop entrance scheme (2005 and 2015)

Name of the entrance	Modelled for 2005 (Sc. 24)	Modelled for 2015 (Sc. 240)	Modelled for 2005 (Sc. 2403)	Modelled for 2015 (Sc. 2404)
Islandijos	639	700	609	737
Trakų	613	983	333	627
Arklių	134	223	61	28
Subačiaus	413	725	475	842
Latako	404	865	298	651
S. Gucevičiaus	385	524	661	925
Universiteto	232	440	75	183
Total	2820	4460	2512	3993

6.3. Alternative of the charged entrance

The charged entrance to the Old Town undoubtedly will influence the selection of travel route and will divert the traffic flows to roundabout streets (Jamshid 2006). However, in order to evaluate this alternative, it is necessary to refer to certain assumptions or to examples from other cities.

In this case, the modeling of traffic flows is not beneficial and it requires a wide range of additional surveys to assess the individual behaviour of the user of transport infrastructure.

The survey showed that the transit traffic in Vilnius Old Town makes up 39% of all entering traffic. A number of people will have one or another reaction to the charged entrance: they will reject the travel, change to public transport, or choose the "park and go" alternative by leaving the car and walking on foot, or share the car with their colleagues etc.

The academic staff of the Dept of Urban Engineering VGTU carried out an expert evaluation of the influences of a charged entrance/road price on the subsystem of private transport (Table 4).

Table 4. Evaluation of the influence of charged entrance or road price

	Influence on transit flows		Influence on remaining traffic flows		Total
	%	Vehicles	%	Vehicles	
Pessimistic scenario	20	4952	5	1936	6888
Medium scenario	27	6685	7	2711	9395
Optimistic scenario	35	8665	10	3872	12538

According to the medium scenario, the total flow of vehicles would decrease by about 14.8%. In the long-term perspective, when all the by-passes of Vilnius City are constructed, the effect of charged entrance/road pricing on the transport system of the Old Town will be even larger and could reach 16–20%.

The use of the system of video cameras is very flexible from the point of view of collecting charges (the residents could pay by the Internet, telephone, or at specific places) and the coordinately controlled system for the management of traffic flows, planned to be installed in the near future, would supplement charged entrance alternative. The latter system optimizes time-delays at the crossings and gives drivers additional (real-time) information about alternative routes in Vilnius.

7. Discussion of the results

Volumes of traffic flows in Vilnius Old Town are related not only to the concentrated variety of businesses but also to the developed structure of the city. From the long-term point of view it is necessary to reduce the number of enterprises and establishments within this territory that has been generating attraction of inhabitants in large numbers.

Three main alternatives have been modelled and analyzed: “Old Town by-passes”, “Loop” and “Charged” entrance to the Old Town. In case of the modelled “Do nothing” alternative a vehicle flow entering the Old Town consists of 2820 vehicles in rush hours (Table 5). The forecasted average annual growth is 5.8% (for 10 years).

Table 5. Summary of modelling and expert evaluation results

Alternative	Reduced number of vehicles (%) in rush hours as compared to “do nothing” scenario	Forecasted annual growth of traffic flows % (for 10 years)
Do nothing	2820 vehicles	5.8
Old Town by-passes	14	6.1
Loop entrance	10.9	5.9
Charged entrance	14.8	4–5

The “Old Town by-passes” alternative shows that after construction of the southern by-pass of the Old Town and the southern by-pass of the city - the flow of vehicles entering the Old Town during the a rush hour would decrease by 400 (14%) vehicles as compared to the “Do nothing” alternative. Meanwhile, the annual growth of traffic flows would be significantly faster – 6.1% (10 years).

The “Loop entrance” alternative has the advantage of restricting traffic flows by including the reduced attractiveness of driving in the Old Town streets. The flows into the Old Town, when compared to the “Do nothing” alternative, in peak hours would decrease by 308 vehicles (10.9%) and the annual growth would reach 5.9%.

In case of the medium alternative, the “Charged entrance” would reduce the entering traffic flow by 14.8%. A tendency for the annual growth of the traffic flows would remain within the limits of 4–5%.

All the analyzed alternatives would undoubtedly influence the decrease of traffic flows. However, it must be taken into consideration that the alternative of the by-passes is already being implemented and work has already started. When thinking about the more distant future, it would be important to decide which alternative has to be

chosen: the “Loop entrance” or the “Charged entrance”. Modelling, expert evaluation and analysis results show that the latter alternative is more advantaged.

8. Conclusions and recommendations

1. The extent of transport flows in the old towns of the towns of Lithuania is linked not only to the concentrated variety of activities and the rising level of car ownership but also the existing town structure. In the long term, it would be necessary to reduce transport flows. The centres and the old towns of Vilnius, Kaunas and Klaipėda should be subject to traffic regulation.
2. The worldwide practice of introducing road pricing in cities showed that before it was introduced it was necessary to clearly define the goals to be reached, e.g. to reduce congestions and environmental pollution, to protect the Old Town and to enhance the town’s attractiveness to tourism; also it is necessary to declare that the collected funds will be used only for developing the public transport and public infrastructure.
3. During the questioning of drivers in Vilnius Old Town it was determined that the transit traffic in the Old Town makes up about 39% of all traffic. This shows that more than 25 000 vehicles per working day cause a negative impact on the tourist and recreational attractiveness of the Old Town.
4. Traffic prohibition (with the help of prohibitive signs) is unacceptable with respect to the business people and residents of Vilnius. Therefore, the more widely analyzed alternatives are the charged entrance/road pricing (charge is not applied to emergency services, special transport, disabled people, public transport, ecologically cleaner vehicles and residents of the Old Town) and the loop entrance to the Old Town.
5. All analyzed alternatives influence the decrease of traffic flows in the Vilnius Old Town. Modelling, expert evaluation and analysis results show that the “Charged entrance” alternative is more advantaged than the „Loop entrance” alternative. The former alternative is also attractive in providing the possibility in 10 years time to collect funds for financing the public transport infrastructure.
6. One of the most simple traffic restriction mechanisms from technological and monetary point of view is the recognition and registration of vehicle number plates which is used in London. There is no need to install additional recognition devices in the vehicle and a minimum number of employees would be enough to maintain this system.
7. The “Charged entrance” alternative is a new means to restrict traffic flows and to harmonize the development plans of the city. Charging should be applied in rush hours on working days (between 7 a.m. and 6 p.m.). Vehicles could be recorded at 7 main entrances to Vilnius Old Town.

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