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MODELLING THE TRANSPORT FLOWS IN MARIJAMPOLĖ (LITHUANIA)

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Abstract. Every town is a framework driven by local inhabitants' needs, filled with the ideas of local planners and influenced by global and local economical conditions. Consequently, it is crucial to find economically reasonable and sustainable infrastructural solutions to many problems which include traffic flow. A comparison and substantiation of various urban transport infrastructure development strategies in small Lithuanian towns and a documentation of these strategies are an essential part of comprehensive urban plans. An analysis concentrating on the town Marijampolė, as a case study, ie modelling transport flows with software VISUM 9.3 and comparison of the infrastructure development strategies are presented in this article.

Keywords: transport flows, four-stage modelling, substantiation of infrastructure development, comprehensive plan.

1. Introduction

Private transport is one of the key issues influencing the life quality in urban areas. With regard to the concept of sustainability, one has to search for facilities to arrange local transport and land-use as the basis of activities and life and with the intention of raising the life quality and with regard to ecological, economic and social dimensions which include the intergenerational dimension [1–2]. Construction or reconstruction of urban transport infrastructure faces a dilemma: What option is better? Modelling such options is the best way for predicting a future situation and forming strategies for Lithuanian cities [3].

The major theoretical approaches explain a two-way interaction of land-use and transport in urban areas. These approaches include technical theories (urban mobility systems), economic theories (cities and markets) and social theories (society and urban space) [2, 4]. Outcomes of these theories of land-use for transport interaction are related to essential factors such as urban density, employment density, neighbourhood design, location, city size, accessibility, travel cost and time.

Model simulations of such patterns of development dominate, though they are associated with a number of assumptions and uncertainties [5]. Despite these weaknesses, different models are useful to predict key trends in the transport sector, eg influences of land-use changes on mobility patterns. These issues are very important for the substantiation of transport infrastructure development in Lithuanian urban areas [6, 7].

Modelling a traffic and land-use phenomenon includes different tasks, eg problem formulation, development of database structures, gathering basic data for the model, developing the model and modelling technique, tuning and validation of the selected modelling method, using the model itself, as well as the evaluation and dissemination of modelling results (Fig 1).

For gathering the input data, different databases and other information sources are useful. Modelling techniques of different phases of traffic modelling are developed either separately or together.

The main aim of this research was to prepare a model of Marijampolė, to examine its transport network and propose future development plans. Since the transformation of an urban structure and the transport infrastructure is a long-term and complex activity, it is essential to rate the proposed elements according to potentiality and the realisation of possibilities and to map out stepwise refinement plans for such elements.

In summary, the following objectives and tasks may be formulated to reach the aim: preparation and calibration

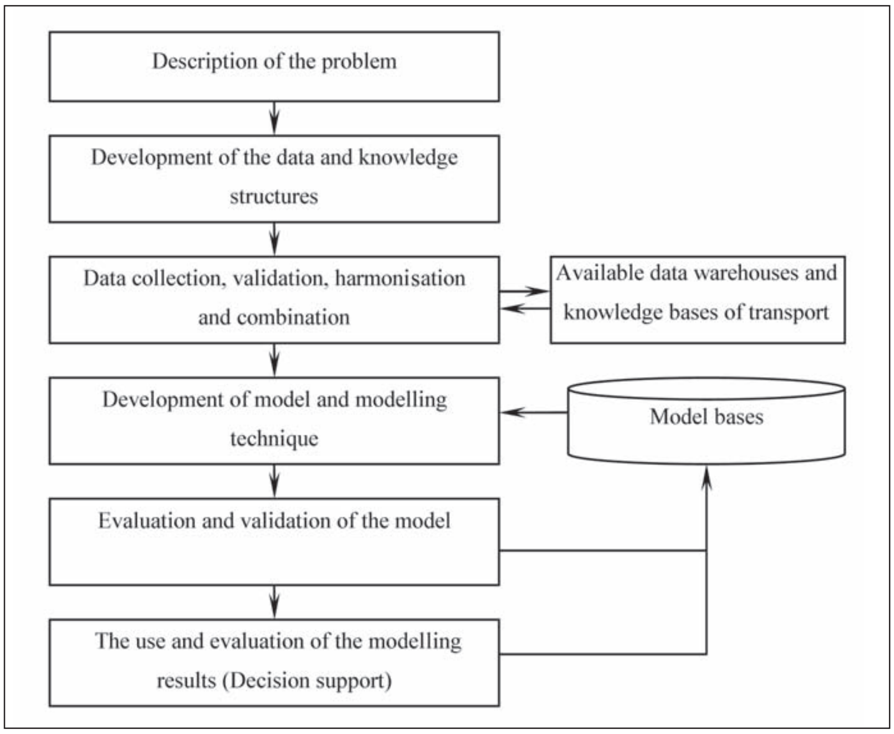

Fig 1. Main components of Transport system modelling

of the model, examination of urban transport strategies and determination of the main preconditions for a more sustainable development of the city/town and its transport system.

2. Modelling software

Software package PTV Vision has been developed at PTV AG, Germany. PTV Vision is one of worldwide transport software suites for transportation modelling that covers all three levels of modelling, namely: a junction, a street network of an individual area, and a street network of the whole town. This suite is distinguished for the integration of all levels and for the ability to import and export data among them, which is really important when modelling different variants in the town. The software suite was successfully applied in more than 75 countries, including EU Member States such as Czech Republic (Prague), Germany, Sweden.

The software suite consists of 3 major programmes: VISUM, VISIM ir CROSSIG. VISUM [8] is a strategic planning system of private and public transport. It is designed for analysis, assessment, and forecasting of transport systems and their environmental impact assessment. The VISIM programme is designed for modelling and visualisation of microscopic transport flows at the town level (a junction, a hub). The CROSSIG programme models and optimises traffic-light operation cycles. The transport flow modelling suite VISUM 9.3 was applied for modelling the Marijampolė transport system.

Transport infrastructure performance at morning rush hours was modelled in 2006. At that time of the day the largest flows to work, school and partially to supermarkets are observed. Hypothetical components of land use and infrastructure development are described in chapters below.

The project focused on finding out the best transport infrastructure configuration within Marijampolė area with regard to urban structure development and population needs as well as on grounding that configuration. With the help of the above-mentioned VISUM 9.3, the current situation was modelled. Later, the focus was shifted to the modelling of the proposed development variants and their comparison with regard to time and fuel economy.

3. Principles of model building

Individual areas of the town feature certain economic activities and land uses. All these activities predetermine certain spatial structure specific to every town and generate attributes of the town area. Human activities also shape the potential of the need for work, cultural, and inward-bound trips, and the transport system satisfies this need. In long-term, the transport system also exerts influence on the land use in the town, as new streets and street decongesting contribute to a better access to territories, and, eventually, create favourable conditions for developing economic activities.

When modelling and assessing volumes of transport flow distribution, the following steps are generally taken (Fig 2): identification of incoming and outgoing flows in a

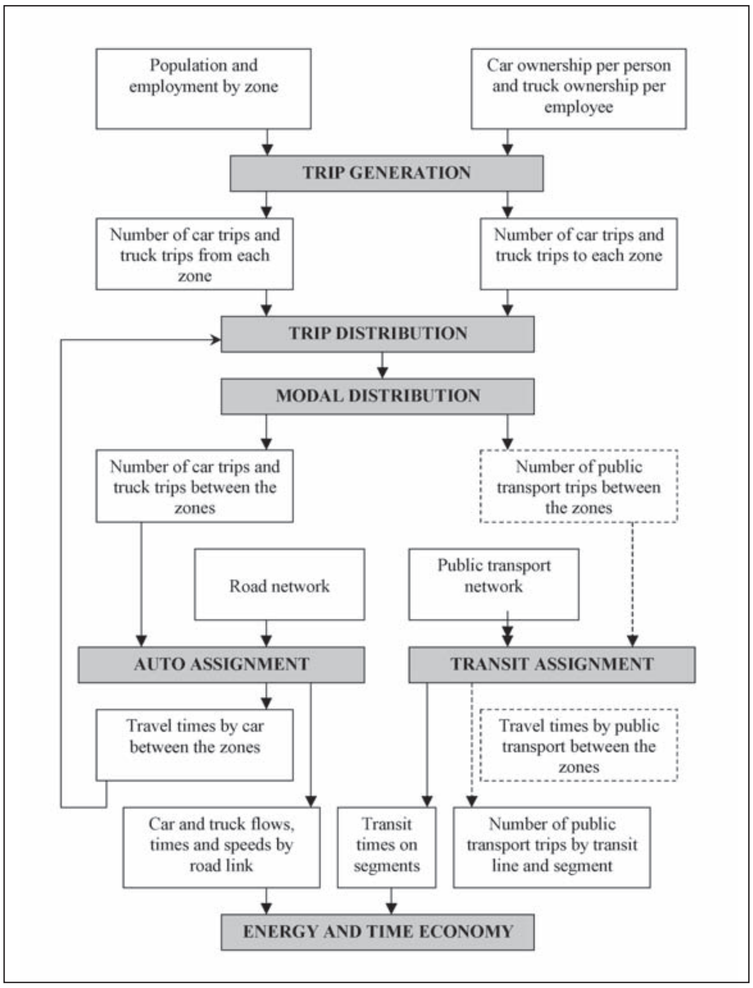

Fig 2. Modelling steps

transport region (trip generation); distribution of flows between individual pairs of transport regions (trip distribution); determination which part of trips falls into a different transport mode (modal distribution); assignment of a trip to a transport network (route assignment).

After these steps are made, the received data may serve as the basis for the applying additional models and for presenting time and fuel economy as these two factors are crucial for selecting the best variant.

Modelling is started by building up a transport network model. This model describes spatial features, capacity, number of lanes, speed of movement and other transport system characteristics. For these reasons, the model consists of several major elements: zones, hubs, links, manoeuvres, connecting elements, stations, and public transport routes.

The integrated network model separates the private transport from the public one. The private transport speed depends on the junction capacity, while the speed of the public transport depends on schedules. The transport system, therefore, consists of several parts that are described by type (private or public) and mode (car, bus, trolleybus etc).

Transport system potential (supply) is related to the need (demand) for travelling. It is related by ways of travelling (modes) and demand segments [8] (Fig 3).

A transport mode can cover one or more transport systems. Generally, private transport modes cover one transport system, while the single public transport mode covers several systems (buses, trolley-buses, trams etc). A segment belongs to one transport mode and there may be several of them (eg students, pensioners, workers). All individual segments are done with the help of matrixes.

The transport system infrastructure (potential) consists of hubs (junctions) and links (streets). A hub must indicate the allowed directions and priorities (a main road, a turn-off) of manoeuvres. Links are described by length, number of lanes, speed, traffic restrictions, and capacity (theoretical capacity of a lane is 1750 vehicles/h [9]).

4. Zoning of Marijampolė town

Town zoning into transport regions is a necessary procedure to define transport needs of population in different town areas (Fig 4). Imaginary places of origin and destination, the so-called centroids, are created in zones. The links

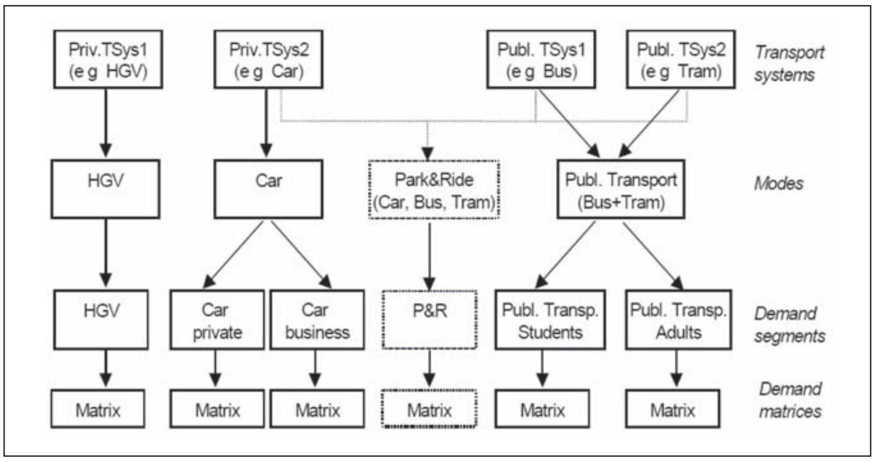

Fig 3. Links between transport systems, modes, demand segments, and demand matrixes

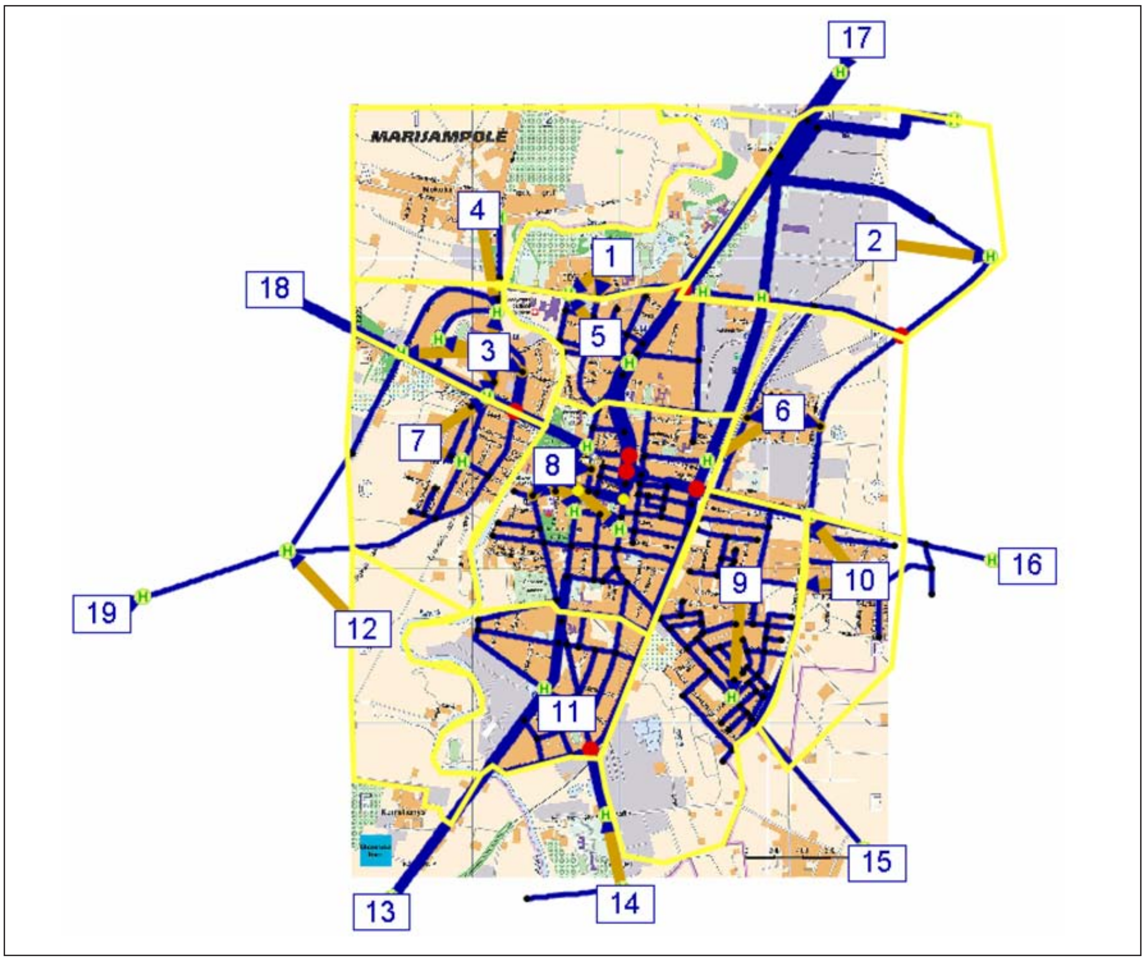

Fig 4. Zoning of Marijampolė town

between such imaginary places and the transport network constitute a linking element.

The arising demand for trips is described in OD matrix (origin-destination matrix). This matrix may be aggregated or separated for the needs of pedestrians, cyclists, users of private/public transport. Marijampolė town was divided into 12 internal zones and 7 external zones. The internal zones define population's connections within the town, while the external ones are imaginary and define connections of town population to out-of-town areas or connections of out-of-town population to town areas.

The following list of attributes was concluded for every transport region [10–12]: number of jobs, number of children, number of working population, number of pensioners, number of students at schools and number of parkings at major attraction objects.

4.1. Trip generation

Population flows at morning rush hours were modelled, and the model describes the following common morning rush hour trips [13]: home-work (generation coefficient 0,6), inward-bound trips (attraction coefficient 0,12), cultural-household trips (generation coefficient 0,12) and trips to school (attraction coefficient 0,7).

It was calculated with the help of the model, that the total number of trips in town per one morning rush hour was 34 000.

5. Trip distribution between transport region groups

Trip distribution between transport regions is carried out by applying an attraction model. In case of work trips, the model formulation is the following:

$$P_{ij} = P_i \frac{d_{ij} k_i N_j}{\sum d_{ij} k_i N_j}, \quad (1)$$

were P_{ij} is trip correspondence between regions i and j; P_i is number of jobs in region i; N_j – number of working population in region j; k_i is gravitation coefficient (generation or attraction); d_{ij} – probability of deployment of working population. Every town has specific gravitation coefficients and deployment of working population. On the grounds of previous surveys, it was proposed to define the probability of deployment of working population with regard to jobs in the town by the following exponentials:

$$d_{ij} = \frac{1}{T_{ij}^n}, \quad (2)$$

where T_{ij}^n is trip time between transport regions, and n – index function. In this stage, a function concluded taking a German town of similar size as an example was applied (also Fig 5) [12]:

$$f(U) = e^{cU}, \quad (3)$$

where $c = -0{,}1$.

Knowing the distances and the average trip time between transport region pairs, this function is applied for distributing all morning trips between region pairs (a joint O-D matrix is formulated).

6. Modal distribution

This step had to assess modal choice of population, ie to find out what transport mode would be used for trips. The model describes one auxiliary and two main ways of travelling by motor transport: on foot (coming to public transport stops), bus and car.

The model defines a mode choice with regard to each type of trip, and specific matrixes were developed (Fig 3). While distributing flows, interim matrixes that outline restrictions (distances, trip time, price) and an auxiliary function that describes choice priorities depending on the distance to be covered (formula 3) in comparison with other ways of travel are developed. For example, for work trips it is assumed that probability of choosing a trip by bus or by car is the same. In case of students' trips, the major part of priority is given to the public transport. Results of modal distribution at the morning rush hours are the following: 10 429 trips by car and 23 884 trips by the public transport.

7. Assignment

Where surveys and theoretical methods reveal the destination and purpose of trips and the mode of transport, the route they usually choose could be found out. To that end,

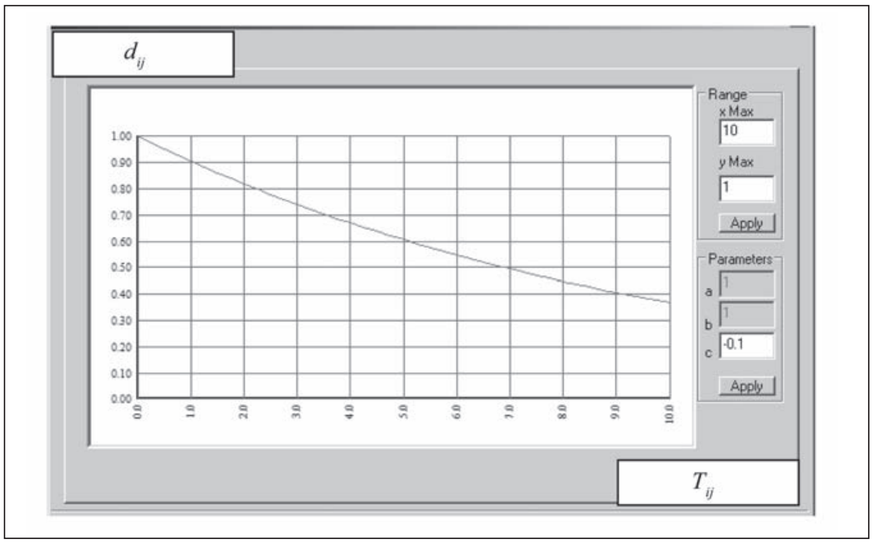

Fig 5. Deployment of working population with regard to jobs in the town

the procedure of flow assignment to a transport network is used. VISUM software suite has 6 assignment methods available: incremental, equilibrium, learning, tribute, stochastic, and dynamic. Choice of a route depends on objective and subjective circumstances but the major ones are the following: likely trip time, route length, and infrastructure dues.

Trip time in a real situation depends on street and junction saturation, and saturation is a ratio of size of the flow and capacity of the street. These elements also change due to weather conditions and a day of the week and may be described taking an account of certain probability. Trip time between two zones depends on access to a car or a stop, trip intervals and idling time at junctions. In the case when a network is congested, flow-delay functions that show the correlation between transport flow size and capacity are used. The final result of this function is a trip time in an over-congested network. VISUM has more than a dozen different flow-delay functions available, and they may be applied when developing the model.

In case of cars, the equilibrium assignment was applied in the model. Trips by cars are distributed on the basis of Wardrop's principle: each driver chooses the route at which his travel time is minimum. Knowing that the number of drivers in town is huge, by choosing another route each of them will prolong his travel time, as well as travel time of other drivers. Equilibrium is reached after an established number of iterations which are started by performing an incremental procedure of assessment is completed. The first iteration is performed changing the number of cars following different routes. A successive iteration checks a condition, whether alternative routes with a lower time input could be found in a network. Verifying this condition, account should be taken of the so-called flow-delay functions that reveal the dependence of trip time on a certain street section on the size of flow (vehicles/h).

8. Modelling variants

The basic variant (2006) was calibrated taking the number of cars on the main junctions at the morning rush hours found out during the survey as the basis. Model reliability was verified applying statistical methods with the key number of observations $N = 27$, and determination coefficient $R^2 = 0{,}79$ (Fig 6).

Results of the basic variant, ie the calculated matrixes of cars and public transport links and cartograms of vehicle flows (Fig 7).

The situation of 2026 was modelled on the grounds of the basic scenario. Growth of vehicle flows was forecasted applying the average flow growth coefficients given in the Road Investment Manual and taking account of flow growth surveys carried out in Vilnius. It is proposed that the average flow growth coefficients are 3–4 % per year [6, 14–16].

Flows keep growing because of the increasing car ownership, changing uses of land in the town and traffic attractors. Drafting the general plan of Marijampolė has only started; thus the land use future is indefinable. In this case, it is necessary to forecast modal distribution in town, ie an increasing influence of a vehicle. The model helped finding out that in 2026 the town cars will make about 20 050 trips per rush hour.

Developing the model of the first variant (Aušros bridge), the *basic variant* was complemented with an additional link connecting Vokiečių street and Aušros street. Developing the model of the second variant (Aušros bridge), the *basic variant 2026* was also complemented with an additional link connecting Vokiečių street and Aušros street.

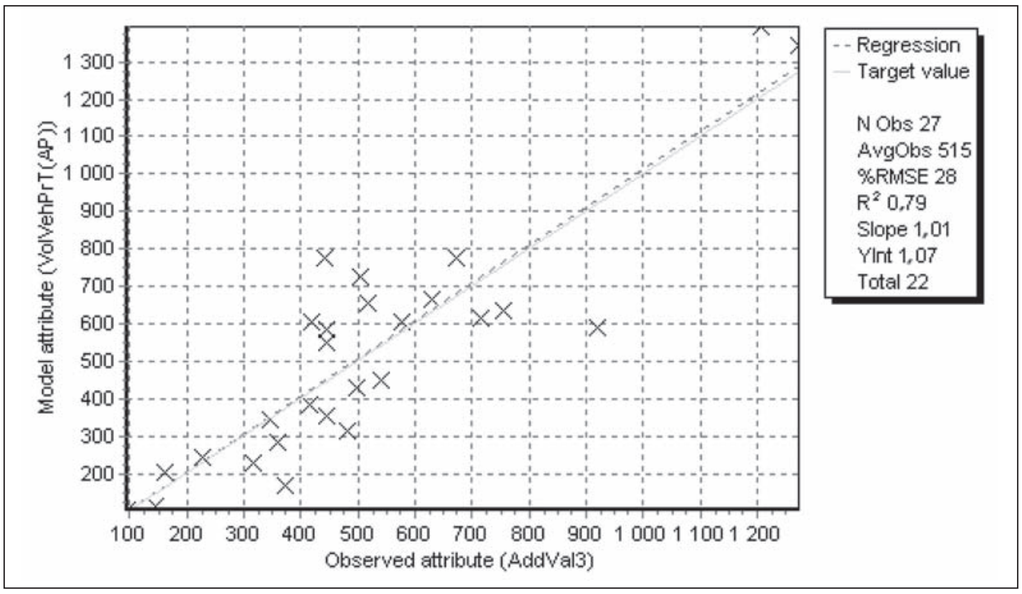

Fig 6. Model verification

With regard to both variants, matrixes of links between cars and the public transport were calculated, and cartograms of vehicle flows were drawn up.

All the modelled variants were compared against the key global level of service indicators (Table). These indicators are also used when assessing the economic payback of the project.

With regard to time economy and average speed, the variant of *Aušros bridge* is the most favourable one. After the bridge is built in 2007, the hourly rush time run in the town would go up, as the bridge would generate additional flows of vehicles. Saving their time people would choose a longer distance (the total average speed in the town would go up after the bridge is built) to avoid congestions in the town central part.

In 2026, the bridge significance in the town transport infrastructure will be even greater, as congestion in the central part of the town will be severe and flows will get concentrated at two main bridges.

Further calculations of fuel and time saving were based on a methodology approved by the Ministry of Communications [6]. Fuel and time economy are the most essential factors when preparing a cost benefit analysis for transport projects. Both factors are evaluated in the methodology and have a very practical monetary expression: fuel price is 2,6 Litas per litre and the average value of one vehicle-hour is 24,2 Litas (in 2006). Economical analysis of *Aušros bridge* scenario showed that economic indicators are *very good:* Internal rate of return – 34,44 %, Net Present Value – 215 479 727 LTL.

9. Compatibility between the street network and the forecast flows

Perspective flows in case if the street network of the town is not expanded were modelled with the help of scenario *basic variant 2026*. The greatest transport flow load will fall to Kauno, Kudirkos, Vilkaviškio streets, and the significance of Geležinkelio, Stoties and Juknevičiaus streets will keep growing. By 2026, if the new bridge is not built, the main western-eastern corridor and, in particular, Vilkaviškio street will reach the limits of its capacity. This only proves the assumption that the new Aušros bridge is an immediate solution, and in further analysis the new bridge is an inseparable part of transport infrastructure.

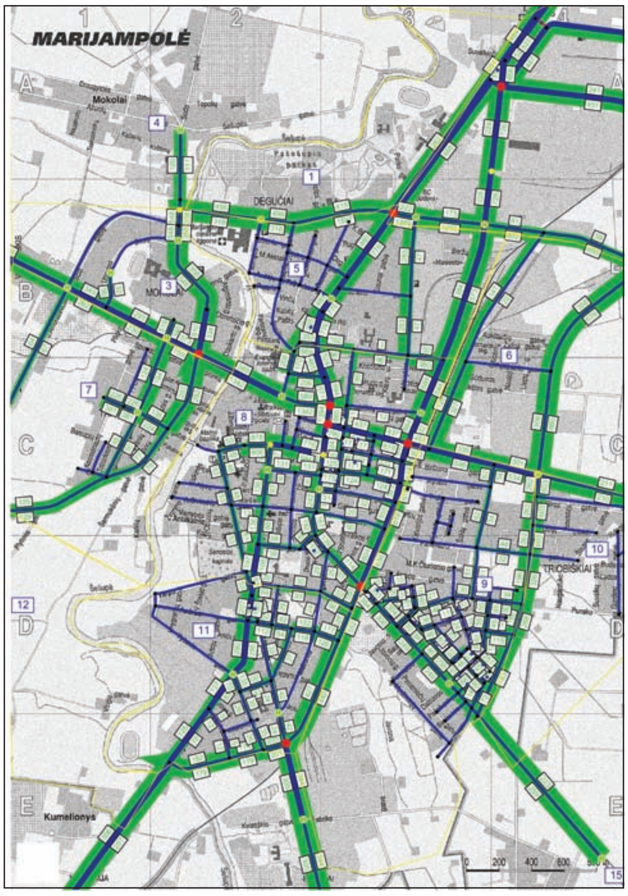

Fig 7. Basic variant of vehicle flow cartogram

The drafted variant *Aušros bridge 2006* revealed that even with the new bridge, the following transport infrastructure elements will remain problematic:

Juknevičiaus street and its junction with Kauno street; the section of Kauno street between Dailidės street and Laisvės street together with junctions within this section;

Comparison of variants with regard to chosen criteria

Criterion	Basic variant 2006	Basic variant 2026	Aušros bridge 2006	Aušros bridge 2026
Modelling results:				
Hourly run at morning rush time, km	31 844	65 871	34 394	67 196
Average flow speed, km/h	35	15	37,3	18,8
Trip duration, h/rush time	906	4408	897	3574
Other indicators (1 – very bad, 5 – very good)				
Impact on traffic safety	3		5	
Level of service	3		5	
Impact on public transport functioning	3		5	
Impact on ecosystem, green areas	5		2	
Transport system reliability, network coherence	2		5	
Integration into urban structure of the town	3		5	

the junction of Kauno street and Girėno street, including new attraction objects.

The last two problems may be solved by reconstructing these junctions and installing traffic-lights with coordinated controls. Such traffic management measures are aimed at decongestion of transport infrastructure. The main measures in this group include road transport telematics and promotion of car sharing. Telematics is traffic management by applying state-of-the-art information technologies. A mere example would be junctions with coordinated controls with *green waves*, and a more complicated example would be real time traffic flow control by choosing optimal speed and proposing alternative routes. In this case, information would be provided and processed in real time. Unfortunately, such systems have not been installed in Lithuania yet; however, strong energy and time efficiency effect could be achieved by installing even less sophisticated traffic control systems [17].

Car sharing is promoted by special privileges. For example, when a car contains three and more people going to work it may use exclusive lanes of the public transport.

Currently, it is obvious that transport infrastructure development in towns generates additional traffic [4, 18, 19]. An idea that a greater number of roads and streets will reduce congestion and pollution and increase the speed are groundless in a long term. This does not mean that street and road building is pointless. However, it should be emphasised that these measures must be applied in line with other measures, eg traffic restriction measures.

Parking dues should be categorised as a short-tem measure of traffic restriction. However, there is no doubt that even low parking prices reduce loading of parking lots but it is necessary to keep the balance of price and vacant parkings. Where no vacant parkings are available, many people may drive looking for parking which cause negative results. Surveys [20] revealed that where parking is facilitated at a working place, many people make use of this and come to work by car. Knowing areas of the town in which jobs are concentrated, the behaviour of population could be governed.

Street over-congestion could be solved by land use strategies, such as management of urban development. Land use in town is formulated and planned in such a way that town structure is as composite as possible, jobs are located closer to residential areas, and urban planning process should integrate public transport planning.

10. Conclusions and proposals

1. Modelling and substantiation of urban communication systems could be performed using modern measures, for example, PTV Vision software suite. Modelling tools are necessary for assessing urban transport systems, comprehensive planning, analysis and forecast of interaction between transport infrastructure and urban development, considering different infrastructure development scenarios, redistribution of working and residential areas, and changes in the level of car ownership in towns.

2. The Marijampolė urban transport system model has been drawn up using the data provided by the Municipality and performing on-site surveys. The basic variant was calibrated taking the number of cars on the main junctions during the morning rush hours found out during the survey as the basis. Model reliability was verified applying statistical methods with the key number of observations N = 27, and determination coefficient R^2 = 0,79. Perspective vehicle flows that would be generated after a new bridge would have been built were modelled on the basis of this basic scenario.

3. Comparison of variants based on the results of vehicle flow modelling allows stating that construction of the new transport bridge in the town will be economically feasible. In all cases sensitivity analysis showed that economic indicators were very good (Internal rate of return – 34,44 %, Net Present Value – 215 479 727 LTL)

4. Modelling results reveal that with the present town structure and with the growth of car use in future, the significance of Geležinkelio, Stoties, Vilkaviškio and Juknevičiaus streets will rapidly grow. In 2026, a vehicle flow in morning rush hours along Vilkaviškio street towards the centre will be 2800 vehicles/hour, on other streets the flow to one direction will be 1000 – 2000 vehicles/hour.

5. The macromodel shows that occurrence of new attraction objects will not significantly increase street congestion during morning rush hours (about 5 %). Results of modelling at afternoon rush hours were obtained using micromodelling of individual junctions.

6. The drafted variant Aušros bridge 2006 revealed that even with the occurrence of the new bridge, the following transport infrastructure elements will remain problematic with regard to vehicle flows: Juknevičiaus street and its junction with Kauno street; the section of Kauno street between Dailidės street and Laisvės street together with junctions within this section; the junction of Kauno street and Girėno street, including new attraction objects. It is proposed to reconstruct junctions and take additional traffic control measures.

References

1. AKINYEMI E.; ZUIDGEEST M. Sustainable Development and Transportation: Past Experiences and Future Challenges. *World Transport Policy and Practice*, 2000, Vol. 6, No 1, p. 31–40.
2. BLACK, J. A.; PAEZ, A.; SUTHANAYA, P. A. Sustainable Urban Transportation: Performance Indicators and Some Analytical Approaches. *Journal of Urban Planning and Development*, 2002, Vol 128, No 4, p. 184–209.
3. BURINSKIENĖ, M. Sustainable Development and Preparation of Comprehensive Plans for Lithuanian Cities. *Journal*

of Civil Engineering and Management, No 7, Suppl Urban Development and Roads. Vilnius: Technika, 2000, p. 3–9 (in Lithuanian).

4. NEWMAN, P.; KENWORTHY, J. The Land-use-Transport Connection. *Land Use Policy*, 1996, Vol 13, No 1, p. 1–22.
5. HOJER, M.; MATTSSON, L. G. Determinism and Backcasting in Future Studies. *Futures*, 2002, Vol 32, p. 613–634.
6. *Lithuanian Road Board*. Manual for Road Investments. Second Edition KIV-04-01. Vilnius: 2004. 98 p. (in Lithuanian).
7. SKRINSKAS, S.; DOMATAS, A. Analysis of Lithuanian Gravel Roads Paving Programme Implementation in 1998–2005. *The Baltic Journal of Road and Bridge Engineering*. Vol I, No 4. Vilnius: Technika, 2006, p. 157–166.
8. *PTV Traffic Mobility Logistic*. Analysis and Planning of Transport Networks, VISUM User Manual. PTV AG: 2004, Germany, p. 1–1–1–18.
9. Lithuanian Ministry of Environment. Regulation STR 2.06.01:1999: Transport Network Systems of Cities, Towns and Rural Areas. Vilnius: Ministry of Environment, 1999. 16 p.
10. Strategic Plan of Marijampolė Municipality till 2010. Approved on Jan 28th, 2005 by Marijampolė Municipality Council Resolution No 1-453, www.marijampole. lt accessed on Jan 06, 2007.
11. General Plan for the Reorganization of Marijampolė Municipality Education Institutions during 2005-2012 Period. Approved on Nov 25, 2005 by Marijampolė Municipality Council Resolution No 1-672, www.marijampole.lt accessed on Jan 06, 2007.
12. Department of the Statistics. Counties of Lithuania 2004. Vilnius: Dept of the Statistics, 2005, p. 33–42.
13. PTV traffic mobility logistic. PTV vision demonstration CD. PTV AG: 2004, Germany.
14. BURINSKIENĖ, M.; PALIULIS, G.; VALEIKA, V. et al. *Organization of Vilnius Transport*: Action plan. Vilnius: VGTU, Territory Planning Research Institute, 1999, p. 8–12 (in Lithuanian).
15. Department of Urban Engineering. Evaluation of G. Vilko-Ukmergės Transport Node Influence on Vilnius Transport System, Final Reports. Ist stage. Vilnius, Department of Urban Engineering. 2004, p. 13–14 (in Lithuanian).
16. Department of Urban Engineering. Evaluation of G. Vilko-Ukmergės Transport Node Influence on Vilnius Transport System, Final Reports. 2nd Stage, Vilnius, Department of Urban Engineering . 2005, p. 22–23 (in Lithuanian).
17. KLIBAVIČIUS, A. Multi-purpose Optimization of Coordinated Traffic Control Systems. *Journal of Civil Engineering and Management*, Annex Urban Development and Roads. Vilnius: Technika, 2001, p. 34–37 (in Lithuanian).
18. RODRIGUE, J.; COMTOIS, C.; SLACK, B. *The Geography of Transport Systems*. Canada: Routledge, 2006.
19. GRIGONIS, V. *Influences of Urban Structures on Energy Resources Consumed by Passenger Transportation*. Summary of Doctoral Dissertation. Vilnius: Technika, 2005. 27 p.
20. LOUKOPOULOS, P.; JAKOBSSON, C.; GARLING, T. et al. Car-user Responses to Travel Demand Management Measures: Goal Setting and Choice of Adaptation Alternatives. *Transportation Research, Part D*, 2004, Vol 9, p. 263–280.

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