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PUBLIC TRANSPORT INTEGRATION INTO URBAN PLANNING

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Abstract. Growth of towns is a result of citizen's social and physical division. Urban planners and scientists have increased the number of links between urban transport and urban development. Public transport has been in the focus of attention as a sustainable and environmentally sensitive transport that brings environmental benefit and possibility to serve mobility needs of citizens without private cars and reduces social division. The article identifies the main factors that affect the use of public transport in town: land use planning; local government policy; extent of economic resources; implementation of modern technologies; social tendencies. Analysis of the scientific literature has revealed four main models of towns of sustainable urban forms: neo-traditional development, urban restrictions, compact town and ecological town. Vilnius has the formed urban and mono-functional structure with a high imbalance between residential and work places which conditions a high mobility of inhabitants as well as high concentration of transport flows on limited-density street networks between the western residential areas and the central part of the City where the main workplaces are located. It presents the provisions of the Vilnius City Master Plan 2015 concerning the public transport improvement. The article also assesses developments in the public transport network in 2003–2009 resulting from changes in individual routes with regard to passenger time necessary for traveling. Modelling is carried out with the help of VISUM software. Citizens of Buivydiškės and Santariškės are mostly affected by the developments, while the situation in Pavilnys, Aukštieji Paneriai and Tarandė has changed only slightly.

Keywords: urban planning, public transport system, modelling of public transport.

1. Introduction

Growth of towns results in their social and physical division. Towns get divided into areas with different purpose, i.e. residential areas, industrial areas, service areas. For example, today it is common that people live in one area, they work in some other area, and spend their leisure in the third area. Such division of the town into areas makes inhabitants increasingly dependent on the transport system. Public transport (PT) has been valued as the sustainable and environmentally sensitive transport that brings environmental benefit and possibility to serve mobility needs of citizens without private cars and reduces social division. Pursuing the main aim, i.e. sustainable integration of PT into the urban development process by optimally satisfying the mobility needs of Lithuania's people, it it's necessary to consider such aspects as general planning of development of residential and business areas, at the same time expanding the priority system of PT.

Accommodated areas, which need different levels of infrastructure of the PT system, are divided by ethnical, social and cultural differences (Fig. 1).

Polish and Swedish scientists investigating the urban transport system has come to the general conclusion that people transportation needs are influenced by territorial distribution of objects that serve the interests of citizens and enterprises (Rudnicki 1999; Vithlani 1996; Waldo 1999).

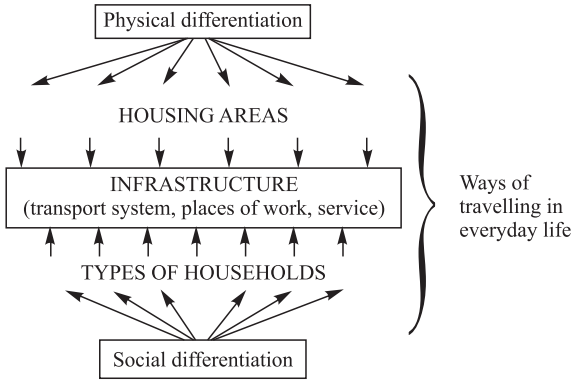

Fig. 1. Impact of the physical and social division on urban infrastructure and modes of travelling (Ušpalytė-Vitkūnienė, Burinskienė 2008)

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The number of links between urban transport and urban development has rocketed during the last century. This was influenced by urban planners and researchers who are looking for a better coordination between the land and transport planning and investment in it (Pinto, Pourbaix 2007).

Urban citizens may travel by car, PT, bicycle or on foot. According to the given scheme, first of all the purpose of the travel is chosen, i.e. a direction, then a mode of travelling which mostly depends on a travel price and time ratio which is not constant. It will depend on a social group of citizens prevailing within the concerned area, which of these factors will be given priority when choose a mode of travel (Eliasson, Mattsson 2000). During the last 50 years the increasing use of private cars and at the same time the development of urban streets have played a major role in the formation of urban areas and sparsely accommodated areas. Increasing pollution of towns, climate changes and other factors contributed to the planners' understanding of the importance of restoring the link between PT and urban development (Eliasson, Mattsson 2000).

Designing society for all citizens, whatever their abilities or social level would be the solution to this situation, and this should be the motivation for sustainable integration between PT and urban planning.

During the last years of the 20th century, the United Nations adopted the *Concept of Sustainable Development* that integrates economic, social and ecological development. In 1992, the Baltic States adopted *AGENDA 21* that besides other conditions incorporates requirements concerning sustainable development of the transport system in the town, namely: support for development and land use management; development of sustainable energy and transport systems in urban areas; creation of healthy environment in the town (Ušpalytė-Vitkūnienė, Burinskienė 2004). Political guidelines set in the *White Paper* published by the European Commission in 1992 recognise that economic growth will automatically result in a greater need for mobility and to meet that need at least partly, PT should take an important position in the future transport system. Rapidly developing and equality-based society needs a reliable and attractive PT system that would provide transport to all citizens, limit pollution in densely populated areas and reduce social division *The Green Paper* published by the European Commission in 2007 notes that community changes and demands more intelligent and accessible mobility solutions. Population expects a more integral and accessible PT system and more flexible transport solutions. Within the framework of *Thematic Strategy on the Urban Environment*, the European Commission has been evoking the concept of a *Directive on Sustainable Urban Transport* since as far back as 2004. The approach makes provision for developing European Union (EU) wide framework specifications on the contents of long-term, strategic and sustainable transport planning for towns and cities with at least 100 hundred thousand inhabitants. These framework specifications should be achieved using specific, locally selected measures. Congestion in towns and cities is one of the main problems identified during previous consultations. Experience shows that there is no single solution to reduce congestion. Alternatives to private car use, such as collective transport, walking, cycling, should be made attractive and safe. Citizens should be able to switch between modes easily. Possible solutions range from good connections between modes, good parking facilities outside city centres, urban charging schemes, better traffic management and information, carpooling and carsharing, and efficient freight transport.

The PT has big attention for a long time as sustainable and environmentally sensitive transport causing environmental benefits and the opportunity to meet the mobility needs of people without private cars, reducing social division (Krygsman *et al.* 2004). Development of new methodologies connecting planning of urban territories and public transport were analyzed by Burinskienė (2009) and Mesarec and Lep (2009). Shifftan *et al.* (2003) and Huwer (2004) have named five key factors that have impact on the use of PT in urban areas:

Land use planning. Land use planning has impact on the size and density of the developed areas, the size and dispersion of industrial areas, distribution of attraction objects for leisure activities within the urban area, and, thus, on the need for PT.

Government policy. Government exerts considerable influence on all solutions that have impact on the level of PT services: from the land use to the management of PT itself. Strong links between PT operators and government representatives make the PT system more attractive for a user.

Extent of economic resources. Larger available sources of financing may facilitate detailed researches of PT, planning at a better founded level, wider PT route network and more frequent services.

Implementation of technologies. Innovative technologies affect a vehicle itself and its speed.

Social tendencies. Mobility of citizens and the modes of travel they choose depend on social groups residing in the town.

In a sustainable transport system of a large and densely populated town, PT should be well developed and accessible in residential and business areas (Hensher, Ton 2002; Herala 2003).

The main aim is to reach sustainable PT integration into the urban development process, optimized to meet the citizens' mobility needs. It is necessary to take into account aspects such as general residential and business destination sites development planning, at the same time expanding the PT priority system that is environment-friendly and safe.

2. Public transport modelling

Growth of towns results in the expansion of their territory, widening gaps in welfare of individual zones and increasing distances from one zone to another. Increasing specialisation of town districts and division of districts into residential, service, trade, industrial and business areas result in the growing need for transport among individual zones and in greater load on the transport system, which requires

greater importance attached to the solution of transport system problems (Wåhlberg 2004). The application of information technologies preconditions the optimisation of performance of transport systems: improvement of the performance quality, safety and efficiency of the overall system, increase in capacity, reduction of the trip duration without high financial investment into construction of the new technical infrastructure. Simulation is the only way to forecast the need for transport in future and the behaviour of the system participants, as well as to plan actions for the implementation of the future scenarios. Thus, the knowledge about transport simulation and about the data used for simulation substantiates the application of the innovative solutions in dealing with the existing and perspective problems of the transport system. The transport modelling is the only economical and sufficiently reliable way to carry out a forward assessment of the impact of the innovations to be applied on the overall system.

Today, a number of software packages used for the modelling of PT have been created in the world. Some of them are the following: VISION, EMME/2, TRIPS, TRAMOD, TRANSPORT, TRANSYT usually used in European countries and America, and GETRAM and ASCII usually used in Asia. These programmes operate in DOS and Windows. The programmes VISION and EMME/2 are most widely used in the world. The VISSIM programme may be used in most engineering disciplines that cover transport planning and traffic flow engineering, where modelling is a necessary instrument for optimisation of the transport infrastructure against substantiation of expenses and their payback. VISUM is the system of information and prognosis for modelling of the private and PT. The integrated network model is divided into two parts, i.e. the private transport system and the PT system. This programme for flow modelling applies 4-step integrated demand modelling: traffic generation, distribution and choice of the mode and route of travel (Duff-Riddell 2005; Murray 2001). The programme models modes and routes of citizens' travels by PT in terms of the minimal price and time.

The morning rush hour, when passenger flows are maximum, was chosen for the modelling. Periodical overcrowding is characteristic of PT and it is most heaviest in the morning and afternoon rush hours (Fig. 2), while at the day-time the need for PT is lower (Shiftan *et al.* 2003). Thus, the need for PT during the morning rush hours is most relevant and was chosen as the time interval of modelling.

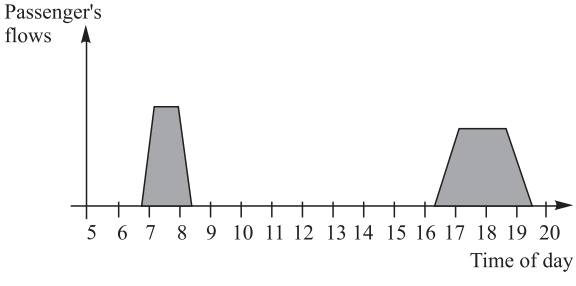

Fig. 2. Excess of PT demand over capacity during the day-time

With the help of the VISUM package, the Kirchhoff distribution law was described as follows:

$$U_i^a = (IPD_i^a)^{\beta}, \quad (1)$$

$$P_i^a = \frac{(IPD_i^a)^{\beta}}{\sum_j (IPD_j^a)^{\beta}}. \quad (2)$$

When modelling with regard to every road under Impedance Index (*IPD*) the percentage of passengers that will choose this road (P_i^a) of the total demand for trips, *i*, on a chosen time interval, *a,* was calculated. Employment of every link U_i^a was calculated in accordance with the trip's distribution function from IPD_i^a.

Factor β is used for defining sensitivity of the IPD. Modelling with the help of the software package VISUM, the following main rule was observed: the lower the IPD of the travel being chosen the greater the number of trips is chosen. IPD is characterised as a combination of the time indicators defined by the user when choosing the travel among transport districts which may be the following: distance to a stop, time spent in a vehicle, the number of transfers, etc.

This indicator in the software package VISUM is being introduced during modelling when the choice of different Original–Destination (O-D) travels is being compared.

3. Models of sustainable urban systems

With regard to the integrated urban and transport planning, four main models of sustainable urban forms are found during analysis of this subject:

Neo-traditional development. Neo-traditional development, or the new urban development, emphasises types of a sustainable urban form that in the transport system planning give priority to walking and to settlements of such size that everything is at a walking distance. In the case of these settlements, slightly higher density is offered than that in typical suburban areas; and to create areas of mixed functional purpose, it is suggested that residential, commercial and public purpose of land use is combined.

Urban containment. In USA and Western Europe up to 95% of development occurred in suburbs in the 7th and 8th decades of last century (Gillham 2002). Such tendencies resulted in a situation where a major part of population lives and works in suburbs and not in town. Urban sprawl is defined as development of low density chaotically situated residential areas and commercial belts dependent on cars. At present, developing European countries including Lithuania have been displaying such tendency, too.

Compact town. Popularity of the sustainable development encouraged promotion of the idea of urban compactness, contributing to the significance of ecological and environmental factors. Since 1990, researches on urban forms mostly were on the side of compact in the space

mixed-function urban areas. According to some scientists, the key advantage of such form is the fact that its offers a possibility to reduce fuels costs while travelling (Hillman 1996; Newman 1989). Among other key advantages are possibilities for secondary use of developed and abandoned urban areas, protection of surrounding landscape and outskirts of the town. Usually, compactness means a densely developed area with intensive activities within it, efficient planned structure and mixed-function areas, and efficient transport systems.

Ecological town. A metaphor of an ecological town covers a wide scope of urbanistic-ecological proposals aimed at sustainable development. These are proposals from environmental, social, and governing authorities aimed at the regulation of urban areas and at making them more sustainable. This concept particularly highlights the issue of ecology and encourages regulation of the development by institutional and political measures. According to Talen and Ellis (2002), the social, economic and cultural plane to an increasing extent predetermines sustainability and spatial structure of the town. Thus, according to this concept the town is being managed aiming at sustainability through different land use, environmental, social and economic policies.

4. Provisions in the Vilnius City Master Plan 2015 concerning the public transport improvement

The main goal of the Master Plan is to create conditions for continuous, socially and economically motivated improvement in the quality of living and for reduction of territorial disparities. This goal is to be achieved employing the measures of sustainable development and through:

- polycentric urban structure;
- multi-functional land use;
- greater social integration, decreased development disproportions;
- foreseeing the PT priority;
- pollution reduction.

The sustainable system of the city and adjacent areas is being created together with neighbouring municipalities to increase international competitiveness of the city and its partners.

The most obvious disparities in the centre and periphery:

- in the centre with the serious problems related to physical quality of residential environment, transport flows and working places concentration, pollution, conflict between pedestrians and transport, social environment;
- in the periphery with the serious problems related to the underdeveloped physical and functional structures, engineering and social infrastructure, insufficient provision of the PT.

Forecast of the city development. The analysis of the external and internal factors that affect the present state and the development tendencies is followed by the forecast of the changes in the factors that affect the development of the city (Table 1).

Table 1. Technical indicators of transport infrastructure of the largest Lithuanian cities in 2009

Technical indicators	Units	Cities	
		Vilnius	Kaunas
Population of the city	thousands	553	352.28
Population density	number/km^2 in thousands	1.392	2.244
Density of streets	km/km^2 to 1000 residents	1.774	2.580
PT passengers	km/km^2 to 1000 residents	6.65	5.67

Vilnius has a formed urban and mono-functional structure with a high imbalance between residential and work places, which conditions a high mobility of inhabitants as well as high concentration of transport flows on limited density street networks between the western residential areas and the central part of the City, where the main workplaces are located.

The forecasts included into the Master Plan (till 2015) reflect the necessity to deal with transport problems in the city and in the suburbs, by devoting special attention to the PT. The key solutions in this field are the following:

- a network of fast PT routes in the city and in the suburbs that consists of modern tram and railway lines (in addition, express buses may be used). A train route in the east-west direction (Trakai–Lentvaris –N.Vilnia–Mickūnai) and modern tram route in the north-south direction (Santariškės–Station–(Airport)). Other economic instruments: priority traffic organisation measures, further development of the PT lanes;
- completion of the trolleybus contact network in the northern part of the city. Network development is foreseen on Šiaurinė and Žvalgų streets from Justiniškės to Žirmūnai and on Laisvės al. and Ateities street to the Fabijoniškės transport hub where the northern terminal of the PT is planned (together with a suburban bus station).

Currently, as the implementation of the solutions of the Vilnius City Master Plan 2015 has not been started, the PT system and its route network undergo continuous changes and improvement, which is done mostly considering complaints of citizens. This article tried to estimate the changes brought about in 2003–2007 and how these changes affected functioning of the PT system.

However improvements in terms of infrastructure and supply can only lead to a partial success. Therefore, PT companies have and are focusing on marketing measures that advance a change of consciousness and attitude towards PT. Among other things, a great emphasis is put on fields such as information, advertising, customer loyalty measures and customer service. Only this way will the customers enjoy the service even more – and therefore increase its use.

Market monitoring can be related to the four classical "Ps" of marketing: price (tariff); product (PT system);

place (distribution/use of tickets); promotion (e.g. advertising); plus the relevant service "Ps": process, people, physical evidence.

A basic method to learn about the transport market are travel behaviour surveys. They include not only PT passengers but (a sample of) the total population so they therefore provide a complete picture of the market. On this basis, a potential analysis is possible which shows the potential for additional customers and how it can be reached.

5. Formulation of the model for the present and the extended public transport of Vilnius City

Two PT models are made to estimate how the length of the travel by PT is affected by planned and introduced transport routes in the newly emerging or changing residential areas.

Since 1990, the dislocation of working places of the citizens of Vilnius have been rapidly changing, industrial areas such as Aukštieji Paneriai, Kalvarijų street, etc. that used to feature the highest density of working places have almost declined. An opened up possibility to move to higher quality housing caused internal migration of citizens of the city. People move to new residential areas that emerge in the peripheral zones of the city. Dynamic changes of the city should cause changes in PT that serves the inhabitants, as previously concluded the plans of PT routes fail to meet the needs for mobility of the present-day population. To make the planning of Vilnius PT system more rational, it is necessary to create its model to streamline the network of the PT routes that meets the new needs of population arising due to changes in their living and working places.

Periodically, PT gets overcrowded especially in the morning and afternoon rush hours. In a day-time the need for PT declines. In the rush hours the key problems of PT become vivid (Baldwin *et al.* 2004; Hensher, Stanley 2003; Stopher 2004). Thus, the need for the PT during the rush hours is most relevant ad was chosen as the time interval of modelling.

The initial model of Vilnius city is made on the basis of the scheme of the PT routes today serving the citizens of Vilnius. Currently, the central part is served by 19 trolleybus routes. Remote residential areas and peripheral parts of the city are served by 72 bus routes. Recently, the route lines which are serve by private operators continuously going down in Vilnius city. They are preferred by people with higher income who need more comfort.

The supplemented network of PT has been expanded taking account the emerging or intensively thickening residential areas foreseen in the Vilnius City Master Plan (Fig. 3):

- in Santariškės the bus routes are expanded to serve Mokslinkų and Mykolo Lietuvio streets;
- in Tarandė the bus route is extended to serve Platiniškių street;
- in Buivydiškės the bus routes are extended to serve Karaliaučiaus and Varnės streets;
- in Grigiškės the bus route is extended to serve Žalvarnių and Lentvario streets;

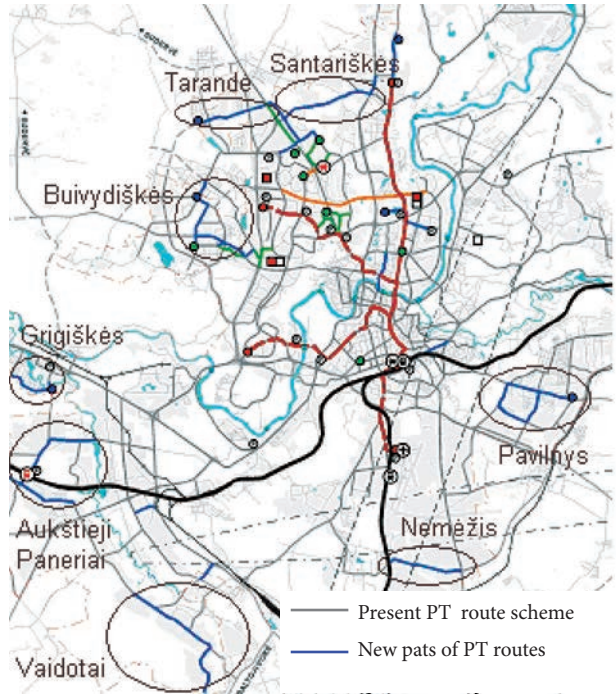

Fig. 3. Places where the PT routes have been expanded (Ušpalytė-Vitkūnienė, Burinskienė 2008)

- in Aukštieji Paneriai the bus route is extended to serve Liepų drive;
- in Vaidotai the bus route is extended to serve Jaunystės street;
- in Nemėžis the bus route is extended to serve Katiliškių and Salininkų streets and Eišiškių road;
- in Pavilnys the bus route is extended to serve Juodupio street.

6. Comparison of the model for the present and the extended public transport of Vilnius City

The main objective of PT modelling is to provide city residents with the highest possible level of PT services. However, the accuracy of modelling results depends on many factors, such as the accuracy of existing route network, timetables, selection of IPD indices and the accuracy of O-D matrix, its size and reflection of the concentration sites of residents.

Due to the extension of the PT routes to serve the newly emerging residential areas, the unit travel matrix became 8 h 57 min shorter. Comparing the travel time of all passengers of PT during the rush hours, the travel has shortened from 1281 days 16 h 13 min to 1273 days 13 h 47 min, i.e. it has become 194 h 26 min or 8 days 2 h 26 min shorter, what is a significant contribution to the time savings for those who use PT.

A detailed expression of the impact of the extended PT routes on each district is given in Table 2 below.

Integration of PT planning into the urban planning process reduces the length of PT trips by the inhabitants

of the newly planned residential districts and this situation influences their satisfaction with PT and the level of its use.

Table 2. Change in the travel time in the affected districts

No.	District	Changed travel time, min	The average change in the travel, %
1.	Santariškės	–681	–2.33
2.	Buivydiškės	–895	–4.19
3.	Aukštieji Paneriai	–29	–0.05
4.	Grigiškės	–204	–0.72
5.	Vaidotai	–74	–0.45
6.	Nemėžis	–84	–0.32
7.	Pavilnys	–17	–0.06
8.	Tarandė	–14	–0.16

The average duration of the travel has been mostly affected by the extension of the PT routes in Santariškių and Buivydiškių districts where the average travel duration has shortened respectfully by 2.33% and 4.19% of the total travel time. In Grigiškės the average travel has shortened by 0.72% due to the extension of the bus route including residential areas, which has shortened the travel time to/from the PT stops. For the citizens living in Pavilnys, Aukštieji Paneriai and Tarandė residential areas, the changed route network has slightly reduced the travel time.

7. Conclusions

Reduction of passenger flows in PT of the city poses a threat on the entire transport system due to the growth of vehicle flow and overload of the network which reached its maximum capacity limits in majority of locations and is operating at the expense of traffic safety.

Vilnius has a formed urban and mono-functional structure with a high imbalance between residential and work places, which conditions a high mobility of inhabitants as well as high concentration of transport flows on limited density street networks between the western residential areas and the central part of the city where the main workplaces are located.

Pursuing the main aim, i.e. sustainable integration of PT into the urban development process by optimally satisfying the mobility needs of Lithuania's people, it is necessary to consider such aspects as general planning of development of residential and business areas, at the same time expanding the priority system of PT.

The use of PT in urban areas is mostly affected by: the land-use planning, local government policy, the amount of economic resources, modern technologies and social tendencies.

Analysis of this subject has identified four major forms of sustainable urban city models: neo-traditional development, urban restrictions, compact town, and ecological town.

Modelling of the Vilnius PT network with the help of the VISUM package showed that the unit travel matrix became 8 h 57 min shorter, or in total 194 h 26 min or 8 days 2 h 26 min during the rush hours.

The greatest benefit is received by those living in Buivydiškės and Santariškės districts, as for them the average travel duration has respectfully shortened by 4.19% and 2.33%, while for those living in Pavilnys, Aukštieji Paneriai and Tarandė districts the charges were not so significant.

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