VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

Kristina GAUČĖ

INTERACTION BETWEEN VIRTUAL AND PHYSICAL INHABITANTS' MOBILITY AND RESEARCH OF ITS INFLUENCE ON URBAN DEVELOPMENT

DOCTORAL DISSERTATION

TECHNOLOGICAL SCIENCES,
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VIRTUALAUS IR FIZINIO GYVENTOJŲ MOBILUMO SĄVEIKA, JOS ĮTAKOS MIESTŲ PLĖTRAI TYRIMAS

DAKTARO DISERTACIJA

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Abstract

Mobility is often understood as an indicator of communication, thus it is one of the main factors influencing cities structure. Limitation of physical mobility possibilities raises up other types of mobility as local or virtual ones and thus changes in cities and its planning. That‘s why it is important as never before to define the correlation between development of settled urban models and virtual mobility and its impact on citizens travelling habits and ways to meet their needs.

In the first chapter research made by Lithuanian and foreign scientists, their results and presumptions related to physical and virtual mobility, mobility management and its integration into planning system based on SD principles have been analyzed. Results from various case studies on mobility are studied in this chapter too. The special attitude was focused on analysis and comparison of Lithuanian and foreign legislation and technical requirements concerning urban engineering and possibilities to integrate MM into LUP.

In the second chapter, after systematic work reviewing methods of multipurpose evaluation, physical research, diaries, statistical software used in practice and analyzing peoples' mobility as a subject of a whole urban engineering with approach of science – the theoretical model for a virtual mobility research was created and presented as outcome.

The aim of the third chapter was to present the estimation of the amount of virtual mobility in Lithuania, to calculate trips to be substituted and arguing with previously published conclusions – to determine modes, distances and time "saved" substituting physical trips.

In the fourth chapter a brief overview about the most important factors for urban planning, main principles and methodology being used till now, its advantages and limitation is made. Virtual and physical mobility research was carried out to define a possibility for physical trips (their purpose, length, transport mode) to be replaced with virtual trips, and to identify the influence of this replacement on the planning of territories and transport infrastructure. Based on the obtained results the main assumptions have been formulated allowing to more effectively plan the land-tenure of transport and social infrastructure and to optimize new construction.

Based on results of this dissertation 10 articles were published. Five papers were published in reviewed publications, the rest in other publications (three of them in Thomson ISI Proceedings). 8 presentations in national and international conferences were done following the results of this dissertation.

Santrauka

Miesto gyventojų mobilumas, dažnai suprantamas kaip susisiekimo rodiklis, yra vienas iš svarbiausių, miesto struktūrą formuojančių veiksnių. Įvairių išorinių veiksnių sąlygoti fizinio mobilumo galimybių apribojimai iššaukia lokalizacinį arba virtualų gyventojų mobilumą, o tuo pačiu pokyčius miestų planavime. Todėl yra kaip niekad svarbu atrasti ryšį tarp nusistovėjusių urbanistinių modelių vystymo ir virtualaus mobilumo bei to įtaką gyventojų gyvenimo ir keliavimo įpročiams ir jų tenkinimo galimybėms.

Pirmame disertacijos skyriuje analizuojami Lietuvos ir užsienio mokslininkų atlikti tyrimai, jų rezultatai bei prielaidos susiję su gyventojų fiziniu ir virtualiu judumu, judumo valdymu, bei jo integravimu į darnios plėtros principais paremtą miestų užstatymo planavimo sistemą; nagrinėjami užsienio šalyse atliktų tiriamųjų studijų ir Europos komisijos kuruojamų tarptautinių projektų rezultatai, galiojantys Lietuvos ir užsienio teisės ir norminiai aktai, reglamentuojantys miestų užstatymą bei mobilumo valdymo priemonių integravimą į teritorijų planavimą.

Antrajame skyriuje trumpai apžvelgiama užsienio praktika renkant ir analizuojant judumui aktualius duomenis bei Lietuvos patirtis šioje srityje, skyriaus pabaigoje analizuota informacija ir kitų mokslininkų patirtis susisteminama ir pateikiama virtualaus tyrimo modelio pavidalu.

Trečiame skyriuje pateikiami susisteminti bei svarbiausi virtualaus ir fizinio judumo sąveikos ir prielaidų tam rezultatai. Skyriaus pabaigoje, apibendrinus gautus rezultatus, parengiamas fizinių kelionių pakeičiamumo virtualiomis modelis. Modelis iliustruoja kokiomis sąlygomis ir kokios tikslinės kelionės gali būti pakeičiamos virtualiomis.

Ketvirtame skyriuje parengus trumpą miesto užstatymo planavimui svarbiausių faktorių apžvalgą, įvertinti pagrindiniai Lietuvoje ir užsienyje naudojami planavimo principai, metodika, reglamentavimas, viso to privalumai ir trūkumai darniosios plėtros ir gyvenimo kokybės atžvilgiu. Parengti penki virtualaus judumo duomenų integravimo į transporto ir teritorijų planavimo procesą modeliai, atsižvelgiant į skirtingus darniosios plėtros kriterijus.

Disertacijos tema paskelbti 10 straipsnių: penki straipsniai buvo publikuoti recenzuojamuose mokslo žurnaluose, trys – konferencijų medžiagose, referuotose Thomson ISI duomenų bazėje, du – tarptautinių konferencijų medžiagose. Disertacijos tema perskaityti 8 pranešimai tarptautinėse konferencijose bei seminaruose Lietuvoje ir kitose šalyse.

Abbreviations

BTR – buildings' technical regulation;
CP – comprehensive plan;
DP – detailed plan;
ESE – elementary services extra;
ESH – elementary services near housing;
EM – Environment Ministry;
ICT – Information and communication technologies;
LR – Republic of Lithuania;
LUP – land use planning;
MM – mobility management;
PP – public places;
PT – public transport;
S – specialized;
SD – sustainable development;
SUT – sustainable urban transport;
VGTU – Vilnius Gediminas Technical University.

Content

Introduction

Problem's definition

Mobility is often understood as an indicator of communication, thus it is one of the main factors influencing cities structure. Increased possibilities of transport mobility create the preconditions for the growth of cities, economical development and qualitative changes in everyday life. Limited possibilities of transport mobility, low quality and high prices of services induce local (change of the living or working place) or virtual (e-work, e-government, e-shopping, e-communication) mobility of citizens.

Changes in mobility possibilities had created not a single "revolution" in urban planning – first of all town's development concept had been completely changed after implementation of public transport systems in bigger towns. Later more and more open conditions for travelling with private cars occurred, this twisted the concept of city's compactiveness, integrality and functionality even more. And finally at the end of the 20^{th} century, urban units were affected by high capacity, digital information networks allowing to do, to get and to find a lot without going anywhere.

According to the data available in Lithuania, nowadays general level of Internet usage is increasing (so far according only to a research made in Vilnius and smaller Lithuanian cities). If we believe in this hypothesis, that physical mobility can be replaced by virtual one – this increase of telecommunications usage should decrease transport flows within a city and should be one of the key measures managing citizens' mobility. So far, a motorization level is increasing, the speed of transportation is decreasing and the average mobility (trips made per day by one citizen) stays more or less stable. Despite the increased possibilities to avoid transport trips, the street jams, pavement deterioration and the number of traffic accidents have been continuously growing too.

The situation described above allows to make a conclusion on prognosis, that virtual mobility as a process itself and its extent as the key impact to physical mobility isn‘t estimated properly, but if it were done – it would be very useful while predicting short and long term transport needs and trends as well as **used for proper planning for new transport infrastructure and effective land use in urban engineering and planning.**

Topicality of the research

To find out the major trends of changes in population mobility, their impact on the cities development in Lithuania and particularly in Vilnius, more attention should be paid to the certain data about population mobility (physical and virtual), their changes depending on certain living conditions and possibilities (of the population), e. g. how the physical mobility is influenced by the increasing significance of the virtual mobility (changes in the length and duration of trips, vehicles, etc.), etc. However, it is difficult to assess the above-mentioned issues by only operating physical numbers, as an information basis of local and virtual mobility does not exist. It could be forecasted that the virtual mobility will rapidly expand and, if this prognosis comes true, it is probable that the physical mobility will decrease and this will result in lesser loads during rush hours. As this trend is seen as a reduced concentration of mobility, it will naturally solve the problem of the transport system.

Virtual mobility as a part of general mobility requires additional attention from transport and land use planners. If virtual mobility is substituting physical trips it has an impact on urban planning as well, fewer cars, less parking, less land occupied in the city centre. More virtual socializing – less necessity for public spaces, cycling routes or social infrastructure. There are many questions to be answered. For this reason the rank of research has to be carried out to define a possibility of physical trips (their purpose, length, transport mode) to be replaced with virtual trips, and to identify the influence of this replacement on the planning of territories and transport infrastructure. Based on the obtained results the main assumptions can be formulated allowing to plan more effectively the land-tenure of transport and social infrastructure and to optimize the demand of new constructions.

The object of the research

Physical and virtual inhabitants' mobility interaction and its influence on urban engineering.

The aim of the research

The main aim of this research is – to design the actual model of physical trips being replaced by virtual ones (hypothetical model of virtual mobility and its dependence on external factors).

The tasks of the work

1. Based on author and the results of earlier research to determine the concept of virtual mobility and virtual trips.
2. After introduction of possible methods for virtual mobility research to create theoretical model for virtual mobility research.
3. To identify the most important social – economical factors influencing the trip choice and preconditions for physical trips to be substituted by virtual ones.
4. To find out which and how many physical trips can replace virtual trips.
5. Estimating virtual trips as measure for mobility management to suggest changes in existing methods of transport infrastructure planning.
6. Estimating virtual trips as indicator of social needs to suggest recommendations for planning social infrastructure.

Methodology of the research

Hypothetical models for virtual mobility data integration into the land use and transport infrastructure planning process were created after surveying methods of physical research used in practice, statistical data processing and analysis as well as multicriteria assessment. Lithuanian and foreign authors' scientific publications as well as other scientific and informational editions, statistical data and research results of the author together with VGTU Urban engineering department were taken as background for this work.

The most significant indicators when choosing the type of the trip were determined using the method of multicriteria complex proportional assessment, created by VGTU scientists. Physical research was performed using communication diary and appropriate survey. For a quantitative analysis of available data the SPSS software was selected and the specially adjusted for this software Clementine's rule induction algorithm.

Scientific novelty of the work and its importance

The author had designated that mechanism for legal mobility management integration and so virtual mobility data usage into land use planning process exists and virtual mobility data could be adopted in: transport infrastructure plans, social infrastructure plans, parking regulation through BTR. **This interpretation of citizens' virtual mobility data** (e. g. the fact that people are avoiding trips on foot longer than 800 m indicated the need for special infrastructure or the fact about lack of infrastructure) **is the main originality of work results and its value for civil engineering.** The following results important for the science of civil engineering were obtained:

1. Settled and determined the model of physical trips substitution by virtual ones.
2. It was determined in what circumstances and preconditions virtual mobility model can be used in urban engineering and transport infrastructure planning;
3. The following principles of SD five models for mobility management integration into land use planning were designed;
4. The principal recommendations for changes in buildings technical regulation based on virtual mobility data were prepared.

Practical value of obtained results

Results got from research and a designed model of virtual mobility broaden information about citizens' mobility which is used in the process of urban development and could be used for forecasting citizens' social and daily needs and planning systematically new development as well: effective land use, optimal building resources for maximal satisfaction of citizens' needs and so assuring better life quality.

Based on results of research carried out recommendations for changes and supplements in buildings technical regulation, setting standards for cars and bicycles parking in a city were suggested as well as principled provision for social infrastructure layout within living district was prepared.

Theses to be defended

1. There are both physical and virtual trips existing, therefore the concept of “virtual mobility” has to be integrated into the scientific studies of citizens’ mobility and sustainable urban development.
2. Due to the impact of virtual mobility physical mobility changes in time and space.
3. Virtual mobility in a particular case could be used as MM measure or reasonable grounding for building requirements (their changes).
4. Usage of virtual mobility model is purposeful in planning transport infrastructure.
5. Usage of virtual mobility model is purposeful in planning social (the living environment of particular target groups) and commercial as well as public buildings constructional area (with aim to optimize general-use, work place and parking spaces).

Approbation of work results

Based on results of this dissertation 10 articles were published. Five papers were published in reviewed publications (one of them in the Web of Science), the rest in other publications (three of them in ISI Proceedings). 8 presentations in national and international conferences were done following the results of the dissertation:

1) Development of Accessibility and Atracttiveness of Vilnius. International conference “ECOMM 2006”. Holland, 10–12 May, 2006;
2) Importance of Science and New Technologies in Mobility Management and Sustainable Communication System Development. Regular Session on Infrastructure Development and Planning. Taiwan, 27 May, 2006;
3) Virtual mobility’ influence on physical mobility. National conference „Civil engineering and geodesy“, Lithuania, 27 September 2006;
4) Will Virtual Mobility Replace Physical Mobility? International conference „Urban Transpot 2007“. Portugal, 3–5 September, 2007;

5) „Integration of Mobility Management Into Territorial Planning Process in Lithuania“. International conference „Environmental Engineering“. Lithuania, 22–23 May, 2008;
6) “Possibilities to Integrate Mobility Management Measures into Land Use Planning”. Workshop within EU project MAX. Lithuania, 11 July 2008;
7) “Proposals for Mobility Management Measures Implementation in Brownfields (Velga case study)”. Workshop within EU project MAX. Lithuania, 11 July 2008;
8) “Mobility Management and Urban Planning in EU New Member States”. International conference “ECOMM 2009”, Spain, 13–15 May 2009.

Structure of the dissertation

The dissertation consists of the introduction, four chapters, and generalization of results (conclusions), lists of references and authors’ publications and four appendices.

The volume of work done – 135 pages (appendixes are excluded); in the text 8 numbered formulas, 27 figures and 57 Tables were used. In this dissertation 102 references were reviewed and cited.

1

Review of mobility and its importance in sustainable urban planning

Limited possibilities of transport mobility, low quality and high prices of services induces to take account of a new way in studying mobility and paying attention to different alternatives to physical communications: local (change of living or working place) or virtual (e-work, e-government, e-shopping, e-communication) mobility of citizens.

Therefore research of Lithuanian and foreign scientists, results and presumptions related to physical and virtual mobility, mobility management and its integration in the planning system based on SD principles have been analyzed in this chapter; results from case studies made independently or within international research projects within EC are studied too. Special attitude was focused on analysis and comparison of Lithuanian and foreign legislation and technical requirements concerning urban engineering and possibilities to integrate MM into LUP.

Based on the findings of this chapter 2 articles were published (Jauneikaite, Uspalyte-Vitkuniene 2004; Burinskiene, Jauneikaite 2005).

1.1. Changes in the usage of communication means during the last decade. Advantages and disadvantages

Motorization and computerization level in both the continent of Europe and Lithuania has been increasing rapidly during the last decade. Although some basic changes between Europe and Lithuania, forcing to pay special attitude to this situation are – the level of changes in car ownership in Lithuania is increasing very significantly every year, although the usage of telecommunication is more obvious in the rest of Europe than in Lithuania. However the problems faced in all the countries are the same – a range of environmental and other problems, including the increasing city-centre congestion, high accident rates and a general worsening of environment quality. The main aim of this subchapter is to determine correlation between motorization and computerization level and its possible impact on urban engineering process.

1.1.1. Changes in transportation and travelling behaviour

Motorization level in Lithuania has been rapidly increasing; if in 2002 there were 340 cars per 1000 inhabitants, in 2005 this number came up to 426, in 2008 even to 506 cars per 1000 inhabitants (*State Enterprise Regitra, Department of Statistics 2002, 2006, 2008*). At the same time motorization in the city of Vilnius was even higher – while there were 325 cars/per 1000 inhabitants in 2001, 450 cars/per 1000 inhabitants in 2005 (Burinskiene, Jauneikaite 2005) and 583 cars/per 1000 inhabitants in 2008.

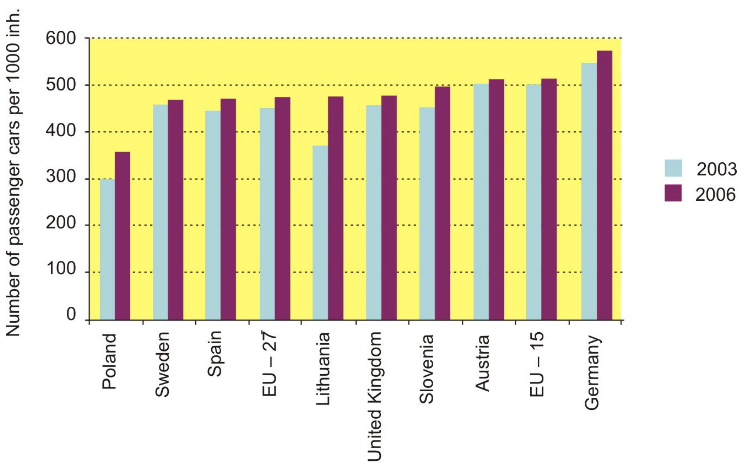


Fig. 1.1. Car ownership EU, 2006

Car ownership in Lithuania in 2006 already exceeded the average number of personal cars per 1000 citizens (Fig. 1.1).

According to the information concerning mobility in Europe (EU transport statistical pocketbook) a part of trips made by main transport modes (PT and car) during the last 25 years was increasing annually and by the end of XX century was equal to 92.4% of all trips made. At the same time the number of km /one inhabitant per year increased almost two times – from 7336 to 13927 passenger km /per inhabitant (Burinskiene 2003).

In USA passengers travel 2.2% more in average every year (Burinskiene 2003) and the number of trips done by main transport modes in 2001 made up 93.4% of all trips (Sammer *et al.* 2002).

At the same time mobility (number of trips per one inhabitant per day) in Lithuania was decreasing from 3.29 in 1971 to 2.84 in 1993 (Juškevičius 1995) and was even lower in 2006–2007.

In the Fig. 1.2 the modal split and changes in Vilniaus trips by modes in 1982-2005 (Juškevičius 1995, Vilnius Comprehensive plan) are presented. Compared to modal split in smaller cities, the situation was always "more sustainable" than in Vilnius, e. g. in Marijampole at 1979 the shift of trips made by main transport modes was only 53.2 (Буринскене 1980).

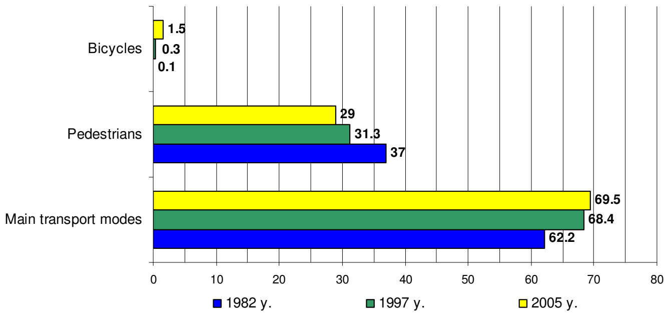


Fig. 1.2. Modal split of trips in Vilnius 1982–2005

The presentation of such old data and comparison with some available nowadays (though there is no official mobility database in Lithuania, nor in some other European countries) is not accidental. This shows differences between Lithuania and Europe in physical number and the same tendencies if we compare changes in percents. All together allows us to make few following assumptions such as:

- a number of the trips made per day are decreasing.
- the modal split of transport means used for daily travelling is changing towards less and less sustainable transport system;

- the length of the trips (km) as well as time spent in trips is increasing;

These changes had been caused by various economical and social factors, at the same time changes in citizens' travelling behaviour caused a range of environmental and other problems.

Every day the problem typical of all cities becomes more acute: traffic jams on the main streets, high accident rates, worsening quality of environment, social dissatisfaction, fear to be late, fear to get injured, etc. Episodic reconstruction of intersections, widening of streets, building of new structures not only fail to solve the above-mentioned problems but even worsen them when during such reconstructions traffic is paralyzed on the main streets (Burinskienė, Jauneikaitė 2008). It also causes additional problems like costs of land use planning related to the taking of land for the right-of-way (Čygas *et al.* 2007), conflict of interests as the owners of the land to be taken off are involved and it requires the solution to be operative and a big demand for investment, which finally doesn't lead to the expected benefit. Situation in the towns (Vilnius, Kaunas, Klaipėda) becomes worse; and what is really sad is that this situation develops also in smaller towns of Lithuania which causes more dissatisfaction of the population of regions than that of the population of bigger towns. All the mentioned above factors are not only worsening life quality in cities but encouraging migration from cities to suburbs (Burinskiene 2003), which increases citizens' daily mobility and worsens the situation as well. Therefore only sustainable transport system, satisfying everybody's needs, which allows to meet citizens and guests daily needs can encourage social, industrial and other activities within cities (Burinskiene 1998, Lahrmann 1998).

1.1.2. Changes in telecommunications

This subchapter will analyze the usage of PC, Internet and mobile phones (ownership of telecommunications means, changes in using purposes, services available, time spent for it) – a short analysis according to the European and Lithuanian data

Lithuania has no database concerning telecommunication usage. According to Global Market Research Specialists ("TNS Gallup", 2008) the number of Internet users (using Internet at least once a week) has increased up to 37 percent in 2008, if compared to 27.7 percent in 2006 (of the surveyed 15–74 year-old residents throughout Lithuania). In 2007 the 35–74 year-old respondents made up 35 percent of the total number of the surveyed Internet users, in 2008 their proportion has increased to 40,1 percent allowing us to suppose that the use of Internet is spreading between the elderly people and thus increasing their virtual mobility and most likely reducing the number of physical trips. Based on the VGTU data in 2008 every second 39–65 year-old Vilnius City resident used the Internet, whereas, in the same year nearly 95 percent of the students had a possibility to use Internet at home. Of course the usage of the Internet (e. g. entertainments on the Internet) evidently does not reduce a traffic flow, that's why the main objective of this article is to determine how physical mobility is changed because of virtual mobility.

As there was no information basis about the telecommunication usage, many citizens' surveys were initiated and done by land use planners or scientists working on particular feasibility studies. These show (RAIT, 2005, 2006, 2007*)* that the use of Internet is spreading among inhabitants of smaller cities as well – 51.3% of surveyed inhabitants of Elektrenai (2005), 53% from Silale (2006), indicated that they use Internet almost daily.

Numbers found in the rest of the world are even more ambiguous. Already in 1998 51% of the total sample (4500) of the Norwegian national personal travel survey (Hjorthol 2002) said they owned a home computer. In August 2000, 51% (54 million) of US households had at least one personal computer or laptop and 41.5% of households had at least one member of household using the Internet at home (compared to only 18% in 1997 (*US Census Bureau*). In 6 years (period from 1995 to 2001) the size of the worldwide number of Internet hosts (computers connected to Internet (Lyons 2002)) has increased by over 1700% (*Internet software Consortium*).

1.1.3. Connection between motorization and telecommunications usage

As it is obvious from chapters 1.1.1 and 1.1.2 both the level of motorization and telecommunication is increasing and so it might seem that there are no direct relations between the car and the computer ownership and the car or the Internet usage as well. But still there is a prognosis, that changes in travelling behaviour are influenced by the increased usage of telecommunication means.

Analysis done by R.J. Hjorthol reveals is a relationship between the ownership of cars and the ownership of computers (PC). While analyzing obtained data from the Norwegian national personal travel survey, he had noticed that 93% of Norwegian who have computers at home, have at least one car in their household, too (41% have 2 or more cars), while only 7% who owns PC doesn't have access to car (Hjorthol 2002). His main conclusion about this fact refers only to a high degree of the same social group who uses the car and the PC and has nothing to do with possible changes in physical mobility allowed by the usage of ICT.

A number of studies have predicted a few decades ago and projected the impact made by online working and services on traffic nowadays, as well (Jauneikaite, Carreno 2009). Within the field of transport, the discussion of substitution of travel by electronic communication has been going on in the 70's already

(Banham 1969, Berry 70); those were predicting mobility changes in time and space according to new development, "electronic" environment and new alternatives to cover citizens' needs. In the debate on how to reduce environmental problems generated by road traffic, and secure a more sustainable development, great hope has been placed on stationary means of communication bringing about reduced daily travel by car (Batten 1989, Capello and Gillespie 1993, Engtrom and Johanson 1996).

In principle all of these mentioned above imply that a physical travel might be to some degree replaced by using the Information and Communication technologies (ICT). But the impacts are not as straightforward as changes in mobility and citizens' travelling behaviour, that's why the main aim of the following chapters is to define mobility itself, its types, possible estimation criteria, ways to manage it and the background necessary for it.

1.2. Mobility types, measurement and management

Every theory of urban development aims at creation of urban environment in which the quality, outcome and price of the town functioning correspond to the aggregate of the main goals (Juskevicius 2004). Among the key indicators of the quality of living are the following: population's mobility, possibility to travel at a chosen time, by a chosen mode, at chosen costs and ability to influence comfort, safety and speed of travelling. As nowadays the mobility concept is quite different than the one used 30–40 years ago, the aim of this subchapter is to analyze different types of mobility, each possible influence on the other and to define main characteristics important for further possible travelling replacement analysis. The other important issue is to find out how to manage citizens' mobility, which is really something more when just supply of new infrastructure.

1.2.1. Mobility, its types and importance

This subchapter is meant for doing a brief overview about Communication mobility generally – trips per day, trips per person, modes of trips, it's importance for city's daily functioning, including info about all possible measurements (speed, time, number of trips, accessibility level, social factors)

Mobility as a term refers to trucking, shipping, aviation, transport, vehicle rental, etc. Population mobility in the city is characterized by the frequency, duration, length, cost of trips and the spread of trips in a concrete urban space, social, economic and other environment (Juskevicius 2004).

The quality of communication usually is described by three criteria: speed, comfort and price (Juskevicius 1995):

- The speed of communication – social, economical and urban category, directly influencing the progress of city and its surroundings, social and economical evolution, territorial development and space for citizens' activities (Juskevicius *et al.* 2008).

- The comfort of communication in a common cab may be characterized by the aspects of city space, which are directly linked with living and working, entertainment and services places and other interests spread in space and time. This is the main factor influencing the convenience, type and duration of a trip.

- The price of communication – category of financial availability of services. One of the prices is the price paid by the user. The other is a price paid by the society for already implemented, maintained and the existing transport system which is still developed. And land issue is directly and indirectly participating as price component.

Thus the aim is not only a maximal speed and comfort as well as a minimal price but the diversity of combinations, which creates freedom to choose trips according to citizens' wishes and possibilities. That‘s why urban structures and their inhabitants try to match different combinations of possible life quality criteria and start to use different alternatives for transportation. For defining it, a closer attention is devoted to population mobility types and their shift depending on certain living conditions and possibilities of population.

Several decades ago population mobility was supposed to be definitely related to the carriage of people and freight by land, water, air transport and travelling on foot (all together – *physical mobility*). Transport does not further satisfy the needs of population mobility, therefore, there are two alternatives to satisfy the required pace of life – *local mobility* (the change of working and living place) and *virtual mobility* – communication means independent on transport system (Juskevicius *et al.* 2008).

All the three (above-mentioned) types of mobility are significant for urban development processes, as they may substitute each other under certain conditions and possibilities. In this process, the quality factors of urban structure and physical availability of transport and other ways of communication are relevant (Juskevicius, Valeika 2007). Localization mobility is excluded from further analysis as substantive type hadn't been analyzed, it was taken into account as the main factor of urban expansion, the main attitude was focused to learn and estimate physical, virtual mobility and their interaction properly.

1.2.2. Physical mobility

Physical mobility could be described as a number of trips made by a person per day or per year (trips/day, trips/year), average speed of trip (km/h), time spent to reach the destination (min/trip), distribution of prevailing transport modes (%), etc. In this work **physical trip** is considered to be a trip made by any transport mode or on foot, having concrete purpose during the respectively shortest time (1–2 minutes) and by respectively shortest route (not less than 200 m) – a separate trip *is not* walking to the public transport stop, trip shorter than 200 meters, action taken on direct way to someone's destination.

The demand of the citizens' communication might be divided into obligatory and elective trips. By their purpose residents' city trips are divided into work-related, household and entertainment trips, by the transport mode used – into the trips by car (private, office, as a driver, as a passenger), by public transport (further PT) (bus, trolleybus, mini-bus, taxi, suburban bus, train) and by non-motorized transport (on foot, bicycle).

When we talk about any type of mobility the users themselves are very important too. Various research made by the author and other Lithuanian and foreign scientists proves once again that different mobility depends on the features of citizens (their age, social status, education, income, gender, living place and etc.).

Table 1.1. Differentiation of citizens' mobility. Vilnius, 1993 (Juskevicius 1995)

The age groups (years)	Mobility, trips. No./1 citizen per day				
	On foot	By PT	By private car		Companies transport
		By bus and trolleybus	drivers	passengers	
7–14	1.59	1.32 (94)*	–	0.08	–
15–24	1.20	1.61 (88)*	0.12	0.09	–
25–34	0.62	1.65 (65)*	0.58	0.17	0.12
35–49	0.56	1.54 (67)*	0.51	0.17	0.09
50–54 fem.	0.45	1.78 (88)*	0.05	0.11	0.08
55–59 fem.	0.36	1.72 (89)*	0.04	0.18	–
50–59 male.	0.39	1.69 (71)*	0.53	0.04	0.11
60–69	0.44	1.10 (76)*	0.20	0.15	–
under 70	0.30	0.78 (90)*	0.02	0.07	–

* PT part (%) in general transport structure

The age, social and economical status of citizens determines the different demand for communication and its possibilities. According to В. Ренкин *et al.* 1981, Juskevicius 1995, all these factors can govern mobility changes among different target groups more than 3.5. The clear differentiation between mobility in different age groups in Vilnius, though at that time when data were collected mobility of younger people was not significantly but bigger than that of older citizens' (Table 1.1).

That's why, according to the experience from other countries, it was forecasted (Juskevicius 1995), that the growth of mobility needs will be even more differentiated:

- The demand of older people to travel by PT should grow;
- Because of a very rapid process of car users "getting younger" and car usage very popular in this age group – the mobility increase in this age group should grow.

These and other prognoses made in 2003 are related with this work, together with VGTU (Urban engineering department) research on young people's mobility. Information provided by respondents on the major vehicles chosen for daily trips is given in Table 1.2 (Burinskiene, Jauneikaite 2005, 2006).

Table 1.2. The prevailing vehicle for the major trips (2003–2005)

Vehicle	Students of Vilnius		Pupils of Vilnius		Pupils of Širvintos town:
	Living outside the campus	Living on the campus	Before mobility campaigns	After mobility campaigns	
Public transport	47 %	**52 %**	33.2 %	26.7 %	23.0 %
On foot	9 %	38 %	54.8 %	60.2 %	**63.1 %**
By car (driver)	**37 %**	5 %	-	-	-
By car (passenger)	7 %	5 %	11.7 %	12.3 %	**12.9 %**
By bicycle	n/a	n/a	0.3 %	0.8 %	**1.0 %**

The public transport is usually chosen by students who live close to the University; such students cover short distances usually on foot and the public transport is chosen for the remaining part of trips (52% of all trips). Students living at a larger distance from the university usually choose a car and usually drive it themselves (37%).

We see that pupils living in a small town are more mobile than students of Vilnius: all pupils had at least one trip per day, while students did not make trips every day (especially those who lived outside the campus). Students who live outside the campus single out the fact that they have only one trip per day (61% of students); so we conclude that this is because most of them use a car for their trips.

1.2.3. Virtual mobility

Virtual – a word used to describe a scenario where electronic means are used to simulate a traditional (physical) way of doing things. **Virtual mobility** refers to the use of the new Information and Communications technologies (ICT) as an alternative to physical mobility (The Virtual Mobility Knowledge Base 2008) and could be described as time spent on the Internet or using a mobile phone with a concrete goal (to do shopping, to find information, to get into contact with the required respondents, etc). In this research it was defined that **virtual trip** is only that activity which with the help of Internet or mobile phone directly replaces a physical trip, otherwise this is called the use of Internet or mobile phone and is not further referred as **virtual trip**. Virtual mobility has both advantages and disadvantages: advantages – virtual trips can be estimated as action replacing transport trips, thus decreasing congestions, making land use more effective, contributing to environment protection, raising some economical impact – saved time and money and disadvantages as well - decreasing physical activity in terms of non – mothorized transport modes used and less socializing outdoors. So one of the tasks of the carried out research was to define the gaps where virtual mobility can be used as a measure for better living quality and sustainable development.

Usually virtual trips by their purpose are divided into three major groups: e-work, e-business, e-commerce and e-services (The Virtual Mobility Knowledge Base 2008).

Lithuania has no information base of virtual mobility. According to ("TNS Gallup", 2008) the number of Internet users (using the Internet at least once a week) has increased up to 37 percent in 2008, compared to 27.7 percent in 2006 (of the surveyed 15–74 year-old residents throughout Lithuania). In 2007 the 35–74 year-old respondents made 35 percent of the total number of the surveyed Internet users, in 2008 their proportion has increased to 40.1 percent allowing us to suppose that the use of Internet is spreading between the elderly people and thus increasing their virtual mobility and most likely reducing the number of physical trips. Based on the VGTU data in 2008 every second 39–65 year-old Vilnius City resident used the Internet, whereas, in the same year nearly 95 percent of students had a possibility to use the Internet at home. Of course usage of the Internet (e. g. entertainments on the Internet) evidently does not reduce a traffic flow, that's why the main objective of this work was to determine how physical mobility is changed because of virtual mobility.

1.2.4. Influence of virtual mobility on physical mobility

Multimodalism is important, in the sense that someone can choose to successfully travel entirely by walking, bicycling, riding transit or avoiding travel altogether via Internet and mobile phone (*Center for Urban Transportation Research, US 2005*). Research by Liu et al. 1998 demonstrates that intermodal transfers are time consuming and are avoided by travellers whenever possible; therefore, the success and functionality of multimodal options require developing them as complete systems that connect intermodally (Jauneikaite, Misiunas 2007).

Mokhtarian (1990) noted that the idea about possible substitution of travel dawned on people soon after the invention of the telephone. It was suggested by

Adams (2000) that virtual mobility and physical mobility are highly correlated and he states "The hope that extensive use of telecommunications will obviate the need for travel and the movement of goods, rest upon a decoupling of the trends of electronic and physical mobility for which there is no precedent". There could be quoted many statements like this in various engineering, transport and social sciences journals; however these were more or less predictions, presumptions, hypotheses not really based on real numbers.

To find out the major trends of changes in population mobility, their impact on the cities development in Lithuania and particularly in Vilnius, more attention should be paid to the certain data about population mobility (physical and virtual), their changes depending on certain living conditions and possibilities (of population), e. g. how the physical mobility is influenced by the increasing significance of the virtual mobility (changes in the length and duration of trips, vehicles, etc.), etc. However, it is difficult to assess the above-mentioned issues by only operating physical numbers, as an information basis of local and virtual mobility does not exist. Residents of Vilnius make use of an alternative for mobility, i.e. communications and information networks. It could be presumed that due to the available opportunities some working places are established at home. Thus, it could be forecasted that the virtual mobility will rapidly expand and, if this prognosis comes true, it is probable that the physical mobility will decrease and this will result in lower loads at rush hours. Since this trend is seen as a reduced concentration of mobility, it will naturally solve the problem of the transport system.

A number of studies have projected the impact of online working and services on traffic. The most optimistic of them projected a possible 38% reduction in car journeys per person per week. This figure includes a 43% reduction in the number of work trips per person per week. Various case studies show evident results of travel substitution by telecommunications:

- home-based teleworking reduced total UK miles by some 1% already in 1993 (estimated by the Review of Telework in Britain, commissioned by the Parliamentary office of Science and Technology);
- commute miles could be reduced by 500 000–1.25 million per year, commute hours could be reduced by 40 000–75 000 per year in Cambridgeshire County (DETR study);
- telework can reduce motor vehicle travel and impacts such as congestion and energy consumption: working at home – 5% less commuter traffic; to avoid traffic queues – 10% less commuter traffic during rush hours; tele- and videoconferencing – 20% less business traffic and a total of 3% less traffic (EU FP6 MAX 2009);
- One UK source (Dodgson 2000) estimates a reduction in car shopping travel due to e-commerce of 10% by 2010 with only a slight increase (0.5%) in travel by delivery vans (Lyon 2002)

There is different reaction to virtual mobility and its promotion, while there is poor evidence of physical trips being replaced by virtual ones, some disadvantages of very high usage of telecommunication are listed and will be analyzed further (like social disintegration of those working at home) in this research. But such obvious advantages as economic benefit, environmental resource consumption, and possible work – life balance (James 2004) and etc. force to take into account virtual mobility as very important in urban environment. If it reduces significantly percentage of trips in countries where some research has been already made, presumably virtual mobility is making influence on transport system and infrastructure in Lithuania‘s cities.

1.3. Mobility management and its relation to different mobility types

Mobility management solves problems of the increasing mobility by cars and citizens' dependence on it and at the same time mobility management by all economical means supports friendlier attitude towards the environment mobility (by increasing the number of trips done by non-motorized and the public transport and by decreasing the number of trips done by car (PORTAL 2003).

Mobility management could be analyzed at two different levels: in wider terms, this phenomenon per se could be understood as a new ambition in the planning system (especially in the new EU Member States, such as Lithuania, Poland, Slovenia); at another level, when mobility management is integrated into the system of strategic and territorial planning, it could be understood as a set of specific measures and tools (EU FP6 MAX 2007, Burinskiene, Jauneikaite 2008).

1.3.1. Mobility management

Mobility management could be analyzed at two different levels: in wider terms, this phenomenon could be understood as a new ambition in the planning system (especially in the new EU Member States, such as Lithuania, Poland, Slovenia, etc.); at another level, when mobility management is integrated into the system of strategic and territorial planning, it could be understood as a set of specific measures and tools (in old EU Member States, such us UK, Holland, Belgium, Scandinavian countries, etc.) (EU FP6 MAX 2007).

In 2007, the participants (represented by the Mobility Research Bureau, Austria of projects (related to mobility management in different countries) financed by the European Commission identified the following main measures for mobility management:

- Information measures (these measures are necessary for providing information to a potential traveller on all possible ways of travelling, this doing with the help of all possible measures (e. g. information on transport services in a local mobility centre, description of alternative travelling ways in press, flyers, trade centers, etc., interactive information during a trip (e. g. in the train) Eltis 2001).
- Promotional measures (the main specific feature of this type measures is that fact that they do not offer any new alternative for the use of a car, they just are aimed at raising awareness and persuasion of population to use certain vehicles that are available at that time (e. g. in Denmark, Germany and Austria *Cycle to work* schemes are popular (Eltis 2008), Munich arranges successful campaigns for new citizens of the city aimed at promotion of mobility without a car, etc.).
- Organization and coordination measures (the name of the measures reveals that they aimed at offering, organizing and coordinating different services to offer (at any price and in some specific area) an alternative for cars in which the driver is the single passenger (e. g. *Car Pool* system coordinated drivers that could carry passengers going the same direction; *Car Sharing* makes it possible to rent a car or a bicycle, where it is needed, or to use the public transport instead of using a private car (also known as paratransit, *Anrufsammeltaxi* in Germany, *Treintaxi* in Netherlands).
- Education and training measures (these measures are aimed at integration of mobility management into training programmes of pupils, students and different professionals (e. g. hotel staff is trained to give information on mobility possibilities in town; courses and extra programmes on mobility management in schools and staff training centers).
- Mobility management measures for a specific situation (in most countries mobility management usually is a means to manage transport flows in specific areas (situations): continuously at large companies, schools, hospitals, recreation places, or periodically during concerts, sport games, fairs. In this case the task of mobility management is to influence ways and modes used by people to move to the centers of attraction. This category of mobility management contains more measures (e. g. school mobility plan, bicycle (car) parking, PT stop, suburban bus stop, etc.).
- Telecommunications and arrangement of a flexible schedule (such measures are usually initiated by certain organizations that replace the need for transport.
- Supporting (integrated into other activities) measures (they could be aimed not at mobility management but they may have significant influence on

population mobility (e. g. they may exert influence on the price of driving a car, limit parking possibilities for environmental reasons, combine event tickers with PT fare, give various discounts, e. g. to bank card holders who use PT).

Assessing the above-given descriptions, mobility management seems a clear and targeted procedure; however, attempts to work in the field of raising awareness of passengers and in the field of mobility management naturally encounters certain issues, therefore, it is important to define the limits and main features of mobility management (EU FP6 MAX 2007):

- Mobility management is oriented not around supply but around the demand. This means that building of a new tram line, bicycle track, street or road should not be considered to be mobility management, as the new infrastructure is a supply not necessarily oriented around the existing needs.
- Infrastructure installation may supplement mobility management measures, as in most countries mobility management usually is used in local importance situation. For example, in hospitals, business complexes, schools and other places with many visitors, a mobility management package also includes the new infrastructure (bicycle parking facilities, PT stops, etc.) but it serves only as an additional measure of mobility management.
- Mobility management should not necessarily be pegged to a specific territory. It could contain tools used on the scale of a town, region or country: mobility centers, integration of several services into one charge system are also understood as mobility management measures.
- Plans of a sustainable town do not imply mobility management but planning of mobility management measures should be one of the components of those plans. Although such measures as priority traffic lanes, solution of congestion and parking problems, levying of streets/roads are typical demand oriented measures, they per se are not considered mobility management, and in this case they are supplementary mobility management measures.
- Traffic organization is not mobility management. However, traffic organization components aimed at making influence on demand and at changing attitude towards alternatives for a private car (e. g. navigation systems broadcasting the real time of train departure) are considered to be mobility management measures.
- Raising passenger's awareness (educative and promotional promotion of sustainable transport modes) is part of mobility management.
- Mobility management also covers cargo transport. Where cargo transport includes transportation of passenger luggage, it should be also considered

in a mobility plan. If this is not the case, then cargo transport organization is understood as logistics.

- Legal framework and price policy also form a part of mobility management if specific mobility management measures that fall within the above-described limits are supported.

In such a context it looks like the mobility is being managed in Vilnius and all over Lithuania too. Every new residential, commercial or any other object, new or reconstructed street, the visit of important foreign guest, changes in taxes and fares, even any bigger accident changes traffic conditions and thus mobility (Juskevicius *et al.* 2008). Episodic reconstruction of intersections, widening of streets, building of new structures not only fail to solve the above-mentioned problems but even worsen them when during such reconstructions traffic is paralyzed on the main streets (Burinskiene, Jauneikaite 2008). Therefore any of these changes isn‘t identified as a factor for present or possible mobility changes, this means that mobility management, as deliberate and purposeful actions are not typical of Lithuania yet (Juskevicius *et al.* 2008).

Application of the above-described measures in Lithuania has been non-coordinated: organization, information or promotion campaigns were not related to the implementation of the new infrastructure or reconstruction of the existing one, introduction of new services, etc. Usually, in Lithuania the above-mentioned activities are carried out by non-governmental organizations (cycling clubs, education establishments, and environmental institutions) and such activities are commonly aimed at a specific goal, not always related to changing mobility habits of population. Even if the application of such measures gives positive results, usually they are not recorded or compared with results of similar activities, therefore, they should be systematized so that application of such measures becomes a means for reducing transport problems (Burinskiene, Jauneikaite 2008).

1.3.2. Relation between mobility types (physical and virtual) and mobility management measures

Telecommunications (virtual mobility) and arrangement of a flexible schedule (such measures are also understood as MM and usually initiated by certain organizations that replace the need for transport travelling with the measures of virtual mobility (phone, Internet) and/or re-arrange the working time (e. g. in Gelre, Netherlands, hospitals keep changing the time of medical treatments for arriving patients; shopping, work, social and other services available by phone or on Internet (in Greece, a birth certificate may be received by post, thus, in Athens, the flow of clients to certain institutions is three times smaller), working time is being changed in many large institutions (they work less days per week and their work starts not at rush hours). According to the surveys (Jauneikaite 2007), the number of students who have Internet at home increased from 75% to 87% per year, time spent on the Internet exceeds two hours per day which allows an assumption that all secondary travels related to services, goods and recreation among the youth "will be carried out onto the Internet" (Burinskiene, Jauneikaite 2008).

Usage of telecommunications by their purpose is divided into three major groups: (The Virtual Mobility Knowledge Base 2008): e-work, e-business and e-commerce: e-services.

There should be established certain institutions for promoting usage of telecommunications and so virtual trips done would be understood rather as MM measure but not as direct virtual trip. There are only two main conditions named in the guidebooks of EC projects (*MOMENTUM, MOSAIC,* PORTAL *etc*.) for such institutions – the services have to be multimodal and easy accessible for potential users. Such institutions can be divided into two types according to the covered area: mobility center – works at city/region level (would be better if it would be governmental or municipal enterprise; or mobility bureau – working at the certain object (institution, university and alike). Such institutions could provide useful information for tourists, employees or visitors of certain target points, help them to avoid some necessary trips and to get services interested people need via Internet.

1.4. Relation between sustainable development, urban planning and mobility management

According to results of the differently defined sustainable development concept (Shen *et al.* 2007, Jauneikaite, Carreno 2009) the main aspects – economical and social sustainability – are without doubts maintaining capacity to meet the needs of future generations.

Changes in mobility possibilities had created not a single "revolution" in urban planning – first of all town development concept had been completely changed after the implementation of public transport systems in bigger towns. Later better conditions for travelling with private cars were created, this twisted the concept of city's compactiveness, integrality and functionality even more. And finally at the end of XX century, urban units were affected by high capacity, digital information networks allowing to do, to get and to find a lot without going anywhere (Fig. 1.3).

Absence of virtual mobility's is making significant influence on the mobility itself. As new concept of sustainable development is very important for cities to be developed nowadays – virtual mobility as one of positive factors in implementing this concept has to be taken into account too.

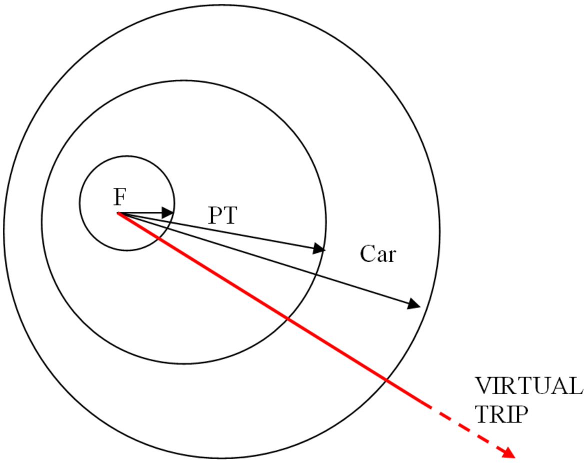


Fig. 1.3. The progress in cities' sizes and mobility development.

1.4.1. Urban engineering and its relation with sustainable development

Sustainable urban development has various approaches and different priorities in different countries (Kaklauskas, Zavadskas 2009). One of the main criteria for sustainable cities development – to have compact and functionally different land use in different cities areas (Burinskiene 2003; Juskevicius, Valeika 2007; Jauneikaite, Carreno 2009) reducing the use of energy and meeting the demands of new residential areas with rationalization of land use (Zavadskas *et al.* 2009).

Based on the multipurpose evaluation of Vilnius city residential areas (Zavadskas, Viteikiene 2007), the most significant criteria for a district to be sustainable are: *the work place is close, clean air, no noise and it is safe*, which raises an idea straight away about the influence of transportation on living quality.

According to the sustainable development concept – new buildings; streets, parking sites and etc. near new residential and public buildings sometimes seem to have rather negative than positive impact on sustainable development:

- economic impact (need for capital, human resources);
- environmental impact (worsened air quality, utilized natural resources);
- personal and social impact (worsened/improved quality of life, health, worsened/improved communication and worsened/improved work-life balance).

When analyzing new constructions related with citizens mobility few factors are taken into account:

- transportation infrastructure (streets and roads);
- parking lots;

- land use in terms of new or redeveloped land for residential, commercial or other use;
- land use in terms of land used for streets and parking lots.

In particular, certain transportation planning decisions tend to increase *sprawl* (dispersed, urban-fringe, automobile-dependent development), while others support *smart growth* (more compact, infill, multi-modal development) (Litman 2006). These development patterns have various economic, social and environmental impacts and obviously smart growth refers more to sustainable development concept while sprawl refers to unmanaged short-term solutions raising the new transportation and life quality problems.

Land use patterns affect the costs of providing public infrastructure and services such as roads, water, sewage, garbage collection, school transport and mail delivery. Various studies (Victoria Transport Policy Institute, Canada) show that these costs tend to increase with sprawl (dispersed development outside existing urban boundaries), and can be reduced with Smart Growth (compact, planned development within existing urban boundaries (Litman 2006).

Parking management refers to various policies and programs that result in more efficient sustainable use of parking resources. In one of Litman's 2006 reports there are described and evaluated more than two-dozen such strategies (*Parking Management Best Practices, 2006*).

1.4.2. Transport planning and its relation with sustainable development

Sustainable transport system in cities is supposed to ensure a choice of transportation according to citizens' needs, estimating their time and budget (European sustainable cities, 1998). Having in mind the definition of sustainable development, transportation nowadays has rather negative impact on sustainable development, as it in most cases refers to a high level of car usage, demand for the new infrastructure and a big impact on the environment. It could be improved by implementing more friendly transport strategy in different stages of strategical and land use planning and thus promoting a decrease in car using, increasing PT, non-motorized transport and telecommunications usage.

Identifying policies that will result in a sustainable transportation system is a major challenge for policy makers since it involves a high level of uncertainty regarding the future effect of a given policy package on the transportation system and the urban environment (Shiftan et al. 2003). According to Shiftan, the key elements in the desired sustainable city transport system scenario are a highly developed public transport system, better coordination between the spatial development and the transportation system, high parking fees, congestion pricing and maintaining the functional role of the city centers areas.

In initiative of EC project SUSTEL (Sustainable teleworking) was held in 2004. SUSTEL conducted 30 cases and 6 surveys in 5 European countries and summarized relationship between teleworking and sustainable development, which in a very broad way could be ascribed to virtual mobility as a whole process:

Usage of telecommunications was economically beneficial in most of the cases (e. g. financial benefits like reduced travel costs, child care teleworking cuts office costs);

Environmental impact – positive on balance through avoidance of congested period and less travel, positive because reduced transport means less emission. But negative when telework didn‘t result in more efficient use of office space, also can have negative impact on transport if flexible offices are not well located for public transport;

Personal and social impacts – almost all the SUSTEL survey respondents felt that teleworking was beneficial for them (employment opportunities for people who might otherwise be excluded (but only in case if people have sufficient working space at home); work life balance improved, although working hours were increased in many of cases, greater involvement in community activities.

The results of previously presented projects and case studies allow to make a strong presumption that virtual mobility, which refers to physical mobility has strong relations with sustainable development and should be taken into account in terms of encouraging sustainable transport and cities development.

1.5. Urban planning and mobility issues

The main urban factors for transportation possibilities within cities are city’s compactiveness and functional structure. Every theory of urban development aims at creation of urban environment in which the quality, outcome and price of the town functioning correspond to the aggregate of the main goals. Population mobility in the city (passengers/km) virtually predetermines a long-term need for the urban transport sector development, its goals, and the infrastructure development. It is stimulated by functioning of the region, territorial development of the town, structural disproportions of regional and urban districts, growth in private income and paying capacity, improving standard of living, and increasing level of motorization (Juskevicius 2004). New town plans should provide the main conception framework of urban transport, include mobility management measures for the coming decade and design transport and social infrastructure solutions based on that, rather than satisfy the existing and forecasted needs of population (building bypasses, widening streets at the expense of green areas, etc.).

The countries that are richer than Lithuania in their main strategic and spatial planning documents have been using such notions as "mobility management", "management of mobility needs" for several decades already. Individual mobility management plans are devised for specific situations, towns, regions, or they are integrated into appropriate detailed, general or strategic plans.

In Europe, especially in the old EU Member States, mobility management often is an integral part of territorial planning and transport infrastructure projects. For example, in the United Kingdom, every administrational level should have a transport plan for every district under its administration (a transport strategy for a region, a local transport plan for local municipality). At the level of detailed plans (its counterpart in our planning system would be a technical project of developed territory), one of the compulsory integral parts of the project is mobility management scheme that solves all issues (including financing of mobility management measures) related to the transport needs of future territory users sticking to the following principle defined in national documents: "Mobility management must be the main means for solving transport problems, especially increase in the car flow due to urbanization of new territories." In Germany, at the level of municipalities general mobility plans (e. g. *Masterplan Mobilität Dortmund)* or *Verkehrsentwicklungsplan* (strategic transport development plans), are devised; and they cover all transport modes in the district in question. Such plans are devised for the period of 5–15 years. More detailed plans, *Nahverkehrsplan*, are devised for five years and they deal with mobility of a specific transport mode (e. g. introduction of the public transport (tram or subway)) or of population in a specifically defined territory (EU FP6 MAX 2008).

For proper usage of this type land use planning system, when integrating mobility management into the planning process, new legal recommendations and awareness of both planners and organizers are obligatory. For proper problem indication and possible mobility management results monitoring a constant data collecting is necessary.

The key principles for integrating mobility management into land use planning are prepared (work is still in progress) by participants of international project "Successful Travel Awareness Campaigns and Mobility Management Strategies" (within the 6th Framework Programme) funded by the European Commission. Recommendations in quotation-marks below are taken from unpublished material "Definition of measures to better integrate transport and land-use planning as a precondition to mobility management; and common analysis frameworks" (EU FP6 MAX 2007) prepared by representatives from Napier University.

"Transport or spatial planners, when considering the LUP system, look to it to produce urban structures that reduce the need to travel, especially by car, and provide better conditions for sustainable transport modes (public transport, non-motorized modes). The literature shows that there are a number of recognized ways that it is believed that such an objective can be brought about. Keys amongst these are the following:

- A poly-centric urban structure where basic needs can be accessed in local centers, with easy access by public transport and cycling to other higher-order centers.
- Medium and high land-use densities with a mix of different uses rather than rigidly separating these uses since, if they are separate, people must travel further to access them.
- Development, especially the kind of development that generates lots of trips (e. g. offices, shops – but also housing) should be concentrated at nodes and along the corridors of the public transport network or at the very least in places that have the potential to become public transport nodes. These areas (nodes and corridors) should be identified in strategic and local plans, possibly by the use of accessibility measurement. Thresholds of (public transport) accessibility could then be set, such that certain types of development are discouraged or not permitted in areas where accessibility levels are below the threshold.
- Re-use of brownfield sites rather than permitting new development on green field sites, as the latter course of action adds to less sustainable urban sprawl.
- When new development is planned, its transport impacts should be assessed and its location should take into account its transport needs. If the transport impacts of the development are predicted to be too large in the chosen location then a different location may need to be selected.
- Parking standards that limit the amount of off-street parking required to be provided with new developments in order to restrain car use to and from new developments.

For their effective implementation, all the mechanisms above should be supported by their explicit inclusion in policy documents from all levels of government that are involved in the LUP process.

In addition, institutionally and organizationally, if planning and transport are to be better integrated, it may be necessary to make organizational changes to ensure that transport planners and land-use planners work together more closely, and to ensure that land-use planners know what transport planners are trying to achieve. This can be the case even if they already work for the same organization, as they are still likely to be working in different sections/departments with different points of view”.

Other factors that influence the building permission decision include, variously, the following:

- The size of the development (sometimes measured in terms of how much traffic it will generate). Larger developments often merit special/different treatment both within plans, and in the building permission process. In Switzerland (Muggli 2007), for example, the canton plays a much more active role in dealing with applications for building permission for large buildings than for smaller, and there are certain categories of development (e. g. large shopping centers) in which the canton has a considerable influence over the building permission decision – although the final decision still rests with the municipality. This is to ensure that the impacts of such developments – which will be felt region-wide - are mitigated.
- Infrastructure provision – municipalities in many countries wish to be satisfied that, before the building opens, utilities and road and footway infrastructure is in place. In some countries such as Poland (*based on "Voivodeship land development plans"*) and Lithuania (*based on Local plans and Rules for Infrastructure development plans*) (based this is limited to ensuring that the development is connected to existing infrastructure; in Ireland, the UK, Switzerland and Germany it could mean that developers pay to upgrade off-site infrastructure that will be put under pressure by the additional impact of the development.
- The environmental impact of the development. This is taken into account in Sweden, both in terms of local plans, and in actual planning decisions – the national level does have the power (albeit it is rarely used) to overturn local decisions on local plans and building permission where it feels that national norms on the environment may be threatened by the plan and/or development. In the Netherlands, larger buildings need environmental permits as well as building permission before they can open, and some municipalities (e. g. Amsterdam) use the environmental permit as a means to lever in mobility management in that organization. (There is currently (Feb 2008) a Task Force in the Netherlands considering whether this way of requiring MM should be made mandatory nationwide, since the environmental permit system applies to existing as well as new developments.). In Switzerland applicants for developments with more than 300 parking spaces planned have to deliver an environmental impact assessment study. These are evaluated by the cantonal authorities and if the environmental impact is considered as too high it can lead to a reduction in the number of parking spaces sought by the applicant. The environmental impact assessment study is a part of the building permit process.
- Parking provision. In many countries, such as Spain, the Netherlands, rural Ireland and Poland, the municipality will normally have to satisfy itself that

at least the stipulated minimum amount of parking is being provided by the developer.

In the Netherlands and Sweden, the development of land also requires a separate agreement between developer and local authority on how that land is going to be used and how the developer will pay for the common costs of the development (e. g. sewage, new roads inside the development). In 2008 a part of the new Dutch planning law will allow local authorities to require contributions from developers for infrastructure that is not on the site, including cycle paths and public transport infrastructure, and to refuse development permission if such contributions are not paid. This is a strengthening of the current situation, where developers make limited contributions to infrastructure (EU FP6 MAX 2008).

As it is obvious from Table 1.3 Lithuania after qualitative evaluation of LUP environment to integrating sustainable transport, LUP and MM (information about status quo in Lithuania towards LUP and existing legislation was collected and delivered to EU FP6 MAX *consortium* by the author of this work), situation in Lithuania is much worse than in other EU member states and even worse than in New Member States (Poland and Slovenia were participating in this research as well). At this time existing planning system in Lithuania is not prepared for mobility management integration into land use planning process (see Table). There are also even more planning levels in some other European countries, but they don't really state the need for such integration. All earlier prepared regulative planning documents note need for transport impact assessment, declare necessity to plan everything with attitude to sustainable development but so far all land use planning documents stop short at planning new parking sites, wider streets and the best that can happen in these documents – plans for new cycling paths and indication of necessary public transport routes, stops and etc.

Table 1.3. Supportiveness of LUP environment to integrating sustainable transport, LUP and MM in EU Member states (EU FP6 MAX 2008)

	National planning policy	National planning law	National land use plans	Local land use plans	Govern-ance structure	Local transport plans	Building permission process	Transport impact assessment process	Parking standards	Freedom of mu-nicipa-lity to operate i	Total
CH	3	3	3	3	3	3	3	3	3	3	39
EI	3	3	3	3	2	3	3	2	2	2	26
ES	3	2	2	2	2	3	2	3	1	1	28
GER	3	2	3	1	1	2	2	2	2	2	29
LI	3	1	1	1	1	2	2	2	1	1	15
NL	3	2	2	1	2	3	1	2	2	2	26
PL	2	2	3	2	2	3	2	2	2	1	27
SE	3	2	3	1	2	3	3	2	2	2	29
SI	3	2	2	1	1	2	1	3	1	2	18
UK	n/a	n/a	n/a	3	3	3	3	3	3	3	30

3 – supportive
2 – neutral impact
1 unsupportive, works against MM
Definitions in the Table
Planning policy – non-binding statement of what LUP should seek to achieve e. g. central place theory in Germany
Planning law – laws governing how the planning system works and the role of specific levels of government and instruments
Land use plans – plans guiding or setting out in detail how land must be developed, which land uses should go where
Governance structure – levels of government, which level is responsible for what functions, and their interrelationships
Transport plans – local or national plans for transport e.g. SUTPs in Spain
Building permission process – the process of granting planning permission for a specific development
Transport impact assessment process – the process of predicting and then planning for the traffic or transport that will be generated by the development
Freedom of municipality to act independently – indicates to what extent does a municipality have to take into account guidance/policies/plans of higher levels of government when making a building permission decision. Higher independence assumed to be less supportive of integration.

Lithuanian land use planning documents are presented in four levels (national, regional, district and local) and three main types (comprehensive, special and local). Attitude to mobility management can appear in all levels and all types of land use planning but more often by the initiative of local (municipal) representatives it finds place in some kinds of strategic planning documents (feasibility studies, investment projects, new development substantiation). Unfortunately these studies don't have legal status so nobody is really responsible for its realization.

Table 1.4. Possibility to use any policy for integrating sustainable transport concept (even MM measures) into LUP

Policy	Possibility	Comment
A poly-centric urban structure	Yes	CP
Medium and high land-use densities with a mix of different uses.	Yes	CP/DP
Concentrating trip generating development along PT corridors	Yes	In theory
Re-use of brownfield sites	Yes	Privately
Transport impact assessment	Yes	Doesn't work
Maximum parking standards	Yes	Since 2008

In Lithuania, declaration of planning of the sustainable transport system is only theoretical, and in reality it is displayed only at the level of traffic organization possibilities and special infrastructure (e. g. a new bypass) studies or projects. Usually, such documents are intended to solve the new infrastructure issues that are related to the existing state of the territory and not to potential development of the new territories (Burinskiene, Jauneikaite 2008). However mechanism for legal mobility management integration into land use planning process exists (see also Table 1.4):

1) one of the tasks and thus obligatory parts in comprehensive plan (for rural area or towns) – is the development of communication infrastructure. In this planning level (*LR TP law, CP rules*) you can put down remark in the regulations table, that for each new development area additionally a mobility scheme has to be made, listing all questions which should be covered by this scheme.
2) one of special plan types – special plans for transport infrastructure (EM rules for communication and engineering infrastructure). These are meant more for new roads, streets layout and reasoning, but us one of the alternatives doing special plans like this might be conception of mobility management given. There are also special plans for new development layout. These are more believable to be useful for mobility management means integration; as such plans cover everything – housing, commercial, public spaces, engineering and communication infrastructure necessary for it.

Mitchell (1999) predicts that in XXI century new infrastructure of telecommunications will remodel urban structures, which appeared as basis of XIX–XX centuries transport, water supply and sewage, electricity and other networks. In 2005 scientists from Centre of Urban Transport Research in their report (Incorporating TDM *(transport demand management) into the Land Development Process 2005*) states, that planning organizations should encourage opportunities for advancement in telecommunications and other technologies and their impacts on travel behaviour to identify other means for meeting some of the transportation needs of the residents and businesses.

Considering a tendency of population for virtual communication, it could be used as one of the instruments for mobility management (e. g. institutions with heavy flows of clients could reduce such flows by making more services available on the Internet). Or taking into account virtual mobility as a part of general mobility, we have to admit that it requires additional attention from transport and land use planners. Knowledge about virtual trips could help: forecasting transport flows (so it's useful for designing streets and oth. infrastructure), forecasting commercial and public places visitors (so it's useful for designing parking parameters and infrastructure to make these buildings accessible), forecasting different society groups needs (so it's useful for land use plan in particular city areas, like a student campus), creating sustainable transport strategy (using knowledge about transport means replaced with virtual trips).

For the meantime, an information base of population mobility does not exist in Lithuania. No on-site or sociological surveys are carried out in a systematic way (Burinskiene, Jauneikaite 2008). For the meantime no information about virtual mobility data usage in urban engineering, land use planning or new construction development haven't been officially published, which allows as to predict that no research and proposals have been done in this area so far.

1.6. Conclusions of the first chapter

1. At present, motorization level in Lithuania is increasing apace; it became 506 cars / per1000 inhabitants in the country and 583 cars / per1000 inhabitants in Vilnius in 2008 (almost the same volume as was forecasted in Vilnius CP for the year 2015. Already in 2006 in Lithuania motorization level was higher than the average in the EU. Meanwhile the number of Internet users (using Internet at least once per week) reached 37% (it was 27.7% in 2006), that shows an increased possibility of virtual mobility. In countries were some research has been already made virtual mobility reduced percentage of trips significantly, so presumably virtual mobility is influencing Lithuania‘s cities transport system and infrastructure as well.
2. The author determined the concepts of virtual mobility and virtual trip, showing differences between **virtual activity and virtual trip**: virtual trip is only that activity when one using the Internet or a mobile phone is directly replacing physical trip and virtual mobility – the entirety of activities illustrating the number of virtual trips per day, purposes of trips and characteristics of physical trips being replaced by virtual ones.
3. The results of analyzed projects and case studies allow making a strong presumption that virtual mobility, which refers to physical mobility, has strong relations with sustainable development and should be taken into account in terms of encouraging sustainable transport and cities development. For the meantime no information about virtual mobility data usage in urban engineering, land use planning or new constructions development have been officially published, which allows us to predict that no research and proposals have been done in this area so far.
4. At this time an information base of population mobility does not exist in Lithuania and the environment of the existing planning system is not open for mobility management integration into land use planning process. However mechanism for legal mobility management's integration into land use planning process exists.

2

Process of virtual mobility and estimation of virtual trips volume in the whole urban transport system

The aim of this subchapter is to make a brief overview about the most important factors for urban planning, main principles and methodology being used till now, its advantages and limitations.

Based on findings of this chapter 2 articles were published (Burinskiene, Jauneikaite 2006; Jauneikaite, Burinskiene 2007).

2.1. The current situation of urban sociology and transport related data in Lithuania

The environment of social problems, especially those related with the implementation of sustainability in any area, is directly related with science. It connects the real world, data, theory (model) for solving a particular problem (Burinskienė, Rudzkienė 2009). Research plays the leading role in taking decisions on the basis of analytical information (Competitiveness of transport services. 2008). There are no doubts that for any prediction, planning and decisions data is the most necessary factor, the second is – a correct analysis of data obtained and its usage (particularly for urban planning).

Different classifications of future process analyses may be found in literature. Traditionally, such type analyses may be classified into 3 (estimating, if-then planning, forecasting) or 4 classes, namely: forecasting, investigative analysis, presumption and projecting. Analysis of the sustainable urban development must be based on a systematic approach. The easiest and most simple way to take a decision is to extrapolate the existing trends However, social, economic and ecologic environments are complex and intertwined, and goals of decisions are not unambiguous, and it is not easy to choose valid assessment criteria (Burinskiene, Rudzkiene 2009). That's why the government's (national or local), planners and/or scientists in the entire world are trying to obtain as more as possible various categories of data important for urban planning (socio-demographic, economical, engineering, cultural and etc.).

In the context of this research, transport and mobility behaviour related factors are the most important as well as external factors influencing them.

The main legislation regulating urban planning and construction in Lithuania is the Territorial Planning Law. All other national law documents concerning territorial planning indicate particular steps for planning and designing simultaneously naming data necessary for further processes, like planning a new bicycle route, designing road or street parameters, setting the minimum number of parking spaces and etc. Annual data on social, economic processes in particular place and all country is necessary. Rules for preparation of cities and towns general plans and Building Technical Requirements state that in a current situation analysis of statistical data of three previous years must be done. Department of Statistics annually provides some statistics about processes in Lithuania's municipalities, although these are far from sufficient for urban engineering. The last which is more important and very useful for planning a survey (*National Inventory*) was conducted in 2001.

Most of the countries arrange national surveys every year (*Transport Statistics Great Britain, Norwegian national personal travel survey, Scottish Household survey, Puget Sound Transportation Panel in the USA*). Those usually are analyzing not only person's travel behaviour but also any details about his/her social status, living place, age, income, family commitments, children, home appliances, car and other transport means ownership and etc.

In 1999, when implementing the EU Phare project (*Statistic of Transport Sector*), a national survey of travelling in Lithuania was carried out to find out personal travelling tendencies of surveyed citizens. By this pilot project it was attempted to show that such type data (direct conversations with the head of the family, individual questionnaires and seven-day journals) might be used to define changing tendencies of travelling behaviour, besides, they might be useful in formation of transport policies, devising strategic forecasting models, etc. The test survey was carried out by the Department of Statistics (Statistics Lithuania); the results revealed that people filled in travel journals rather willingly (only 8% of potential respondents disagreed to participate in survey). The final report does not contain transport related results but it provides constructive recommendations on further arrangement of similar researches (their territorial spread, number of respondents, duration of researches, etc.). The report even gives data on how to monitor individual data in one database containing data on air, surface and intermodal transport. Unfortunately, the survey was not extended and it means that Lithuania lost its chance to have today a 10-year data line (Burinskiene, Jauneikaite 2008).

Therefore the following task – to find out all the most effective ways for virtual mobility and its impact on the whole transport system were set for choosing correct **research methodology**, allowing to answer all the questions raised at the end of the first subchapter.

The following methodology (Fig. 2.1) was chosen for the research:

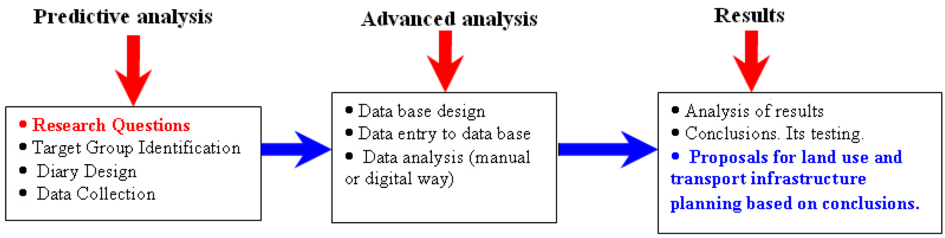


Fig. 2.1. Sequence of research methodology

2.2. Multicriterial data analysis and future trends prediction

While formulating the policy of management of population mobility and planning the new infrastructure, the results of the available analysis may not be a single factor that exerts influence over strategic solutions. Improvement (worsening of) individual parts (solutions) of any person – related process results in causing changes in rationality of the remaining parts and the level of satisfaction of the concerned groups; thus, the first major step in the mobility management should be objective significance of factors (hereinafter – indicators) that have influence on population mobility.

A great part of statistical data has to be understood as a part of sustainable development indicators (criteria) (Burinskiene 2003). Although for objective foreseeing of processes, the comprehensive analysis of various city development criteria has to be done.

The scientists from Vilnius Gediminas Technical University *(E. K. Zavadskas, L. Ustinovicius, A. Kaklauskas, A. Banaitis and N. Banaitiene, V. Podvezko et al.)* and other Lithuanian or foreign scientific and engineering schools have been developing methods for multicriterial data analysis a few decades ago. Evaluation of sustainability for example is also possible using a multipurpose analysis or even the game theory (Zavadskas *et al.* 2005). According to the multipurpose evaluation of Vilnius city residential areas (Zavadskas, Viteikiene 2007), the most significant criteria for district to be sustainable are: *work place is close, clean air, no noise and safe*, which directly refers to the mobility and transportation. Based on that the author did multicriteria complex proportional assessment of factors influencing mobility and citizens' choice and of the most rational and sustainable travelling alternative.

2.2.1. Weight of factors that have influence on population mobility

Multimodalism is also important, in the sense that someone can choose to successfully travel entirely by walking, bicycling, riding transit or avoiding travel altogether via Internet and mobile phone. Research by Liu et al. demonstrates that intermodal transfers are time consuming and are avoided by travellers whenever possible; therefore, the success and functionality of multimodal options requires developing them as complete systems that connect intermodally.

That's why in the below-given estimation of the objective weight and rationality of variants the variant of virtual mobility (e. g., e-banking) is given as one of the alternatives of the trip. To find out the major trends of changes in population mobility, their impact on the city development, more attention should be paid to the types of population mobility, their changes depending on certain living conditions and possibilities (of population), e. g. how the physical mobility is influenced by the increasing significance of the virtual mobility (changes in the length and duration of trips, vehicles, etc.), etc (Jauneikaite, Misiunas 2007). However, it is difficult to assess the above-mentioned issues by only operating physical numbers, as an information basis of local and virtual mobility does not exist.

Thus the objective weight of mobility indicators was defined with the help of entropy method (Ustinovicius, Podvezko 2003, Ustinovicius, Zavadskas 2004). It was assumed that $S = \{S_1, S_2, S_3, S_4, S_5\}$ is a discrete set of variants (trip on foot, by bicycle, public transport, car and Internet (see an explanation below)); $R = \{R_{1,1\text{-}4}, R_{2,1\text{-}5}, R_{3,1\text{-}5}, R_{4,1\text{-}3}, R_{5,1\text{-}4}\}$ is a set of indicators ($n = 21$) groups (overall trip duration, economical issues, quality of trip, environmental impact of the trip, safety of the chosen means); and $X = [x_{ij}]_{5x5}$ is a solution matrix, were x_{ij} is a value of indicator R_j of variant S_i. Following the common understanding about sustainability and its importance to once choice for trip indicators groups $R_{1\text{-}5}$ were supplemented by indicators influencing choice of the trips and its level of sustainability (see Table 2.1).

To have an objective assessment of the 5 variants with regard to all 5 indicators groups, the length of the trip (10 km both ways) equal for all discrete variants and the goal of the trip (work or main daily occupancy related trips, which can be met among various target groups – e. g. business meeting, important examination, try out in the art performance and alike – the purpose of the trip can be achieved using physical as well as virtual trip, it was assumed that target point is well development city are by all means) were taken as a datum-level.

Duration is measured in minutes (see Table 2.1) by estimating the average speed of the trip in the city, the prices are given in litas calculating the average consumption of fuel, the trip on foot, by bicycle or by Internet should be rated symbolically. Quality, the environmental impact and safety are subjective assessments by authoress (Burinskiene, Jauneikaite 2006) in points. The presentation of dimensions and indicators values is presented below:

R_1 – overall trip duration indicators group, contains 4 indicators:

$R_{1,1}$ – the time needed to reach chosen transport mode (car in parking, public transport stop and waiting time for PT, cycling route, estimated in minutes);

$R_{1,2}$ – the time needed for trip (10 km both ways, estimated in minutes);

$R_{1,3}$ – differences in time needed during rush hours (e. g. trip by car can be twice-three times longer in pick time, estimated in times e. g. 2 – means twice longer);

$R_{1,4}$ – time needed to reach target point from end point of trip (e. g. paid parking, bus stop, the end of bicycle route).

R_2 – economical issues indicators group, contains 5 indicators:

$R_{2,1}$ – the price paid by person for single trip (for particular amount of fuel, parking, PT ticket, ownership of bicycle, Internet, estimated in litas);

$R_{2,2}$ – the average monthly price for person using particular transport mean (car insurance, car, bicycle maintenance, fee for Internet or mobile phone and similar, estimated in litas);

$R_{2,3}$ – cost for municipality or developer for land use needed, estimated linear (streets, routes, paths, telecommunications network) and square (parking lots, stops) sizes and presented in points (as the price might misrepresent situation) where 1 means – minimum of land needed; 4 means medium, 7 means maximum;

$R_{2,4}$ – cost for municipality or developer for transportation infrastructure needed (constructional costs), estimated linear (streets, routes, paths, telecommunications network) and square (parking lots, stops) sizes and presented in points (as the price might misrepresent situation) where 1 means – minimum of land needed; 3 means medium, 7 means maximum;

$R_{2,5}$ – cost for municipality or developer for transportation modes purchasing or transportation maintaining needed, estimated in points where 0 – none costs needed, 1 – costs needed for transportation modes purchasing **or** transportation maintaining, 2 – costs needed for transportation modes purchasing **and** transportation maintaining.

R_3 – trip quality indicators group, contains 5 indicators:

$R_{3,1}$ – quality of "trip" needed for reaching transport mode, estimated in points, where 5 – means high, 1-low. Such factors as darkness, fair to be attacked, discomfort of weather conditions, accessibility of transport mode (e. g. going to PT stop, underground car parking, carrying bicycle to cycling route and oth.) are estimated.

$R_{3,2}$ – quality of trip in transport mode (comfort of using transport, e. g. u might not to have chance to sit in PT, u might get wet while walking, u can listen to radio in your car etc.), estimated in points, where 5 – means high, 1-low.

$R_{3,3}$ – freedom to choose start of the trip (e. g. one can choose the start of the trip if u are travelling with car or Internet, but not if you are travelling with PT and only hypothetically can choose start of the trip if you are using bicycle), estimated in points, where 5 – means high level of freedom, 1-low;

$R_{3,4}$ – level of dependence on social infrastructure layout, estimated in points. This indicator estimates how flexible person is to reach the target point with his mode e. g. one can reach any place by Internet or foot, but is dependant of urban layout when is choosing trip by car (restriction for traffic in old town), bicycle (routes are not well connected with target points), PT (development is not always is laid along PT corridors), where 5 – means high dependence, 1 – low.

$R_{3,5}$ – impact on health, rather positive (physical activities) or negative (stress, laziness), estimated in points, where 5 – means high negative, 1-low .

R_4 – environmental impact indicators group, contains 3 indicators:

$R_{4,1}$ – impact on particular person while travelling (gas emission, noise in car, PT and even while walking or cycling), estimated in points, where 5 – means high, 1-low;

$R_{4,2}$ – impact on community in surrounding of corridors generating transport trips (gas emission, noise, fair to be injured), estimated in points, where 5 – means high, 1-low;

$R_{4,3}$ – trip impact on environment, estimated in points, where 5 – means high, 1-low.

R_5 – safety of chosen transport mean indicators group, contains 4 indicators:

$R_{5,1}$ – "social" safety indicators, presenting person safety in particular transport mode or its infrastructure (parking lot, PT stop) and chance not to be attacked, hurt (physically or psychologically) or abused. This indicator is estimated in points, where 5 – means high, 1-low;

$R_{5,2}$ – "technical" safety indicators, presenting chance for person to perform trip in safe way, with high chance not to get injured by other transport participant or by themselves, impact of trips safety according air conditions is estimated as well, basically this indicator illustrates persons chance to avoid accident, estimated in points, where 5 – means high, 1-low;

$R_{5,3}$ – the level of confidence not to be late or to early while using chosen transport mode, indicator is estimated in points, where 5 – means high, 1-low (e. g. the chance to be late is quite high in rush hour, as well as chance to be in place too early, e. g. if person overestimates time for trip in rush hours needed);

$R_{5,4}$ – economical safety indicator which shows the level of chance to be forced to have extra expenses for trip (e. g. parking fee, ticket for speeding and etc.), estimated in points, where 5 – means high level of not to have extra expenses, 1-low.

Thus, the following matrix (see Table 2.1) is obtained:

Table 2.1. Initial matrix for determination of weight

	R_1 - duration				**R_2 - economy**					**R_3 - quality**					**R_4 – env**			**R_4 – safety**			
	1	2	3	4	1	2	3	4	5	1	2	3	4	5	1	2	3	1	2	3	4
F	1	120	1	0	0	1	1	1	1	2	4	2	4	1	2	0	0	4	2	5	5
B	2	40	1,1	1	0	2	2	3	1	2	3	2	4	1	3	0	0	4	1	4	5
P	7	25	1,5	7	5	0	4	5	2	1	2	1	4	2	3	4	3	1	3	3	5
C	3	20	2,5	10	5	150	7	7	1	4	5	5	2	4	5	5	5	3	1	1	1
I	0	1	1	0	0	30	0	1	1	5	5	5	1	5	0	0	0	5	5	5	5
	m	m	m	m	m	m	m	m	m	x	x	x	m	m	m	m	m	x	x	x	x

Where F – means trip made on foot; B – means trip made by bicycle; P – means trip made by PT; C – means trip made by car; I – means trip made via Internet; m – the indicator needs to be minimized; x – the indicator needs to be maximized.

While determining weight some indicators should be minimised and the remaining ones should be maximised, the minimised values of the matrix should be taken in inverse values so that it could be assumed that all indicators will be maximised.

To have the same range of weight, it is supposed that all weights of the initial matrix fluctuate from 0 to 1. Thus, the initial matrix is normalised and with regard to each indicator the efficiency entropy level E_j is determined, which allows assessing the change level d_j of each indicator. As we assume that all indicators are equally important, then the objective weight of indicators is determined with the help of the following formula (2.1):

$$\partial j \to \frac{dj}{\sum dj}. \tag{2.1}$$

Using this method it was determined that the duration of the trip is the most significant indicator groups when choosing the type of the trip (the objective weight: 61% of decision depends on the duration of the trip); the price of the trip is the second most significant indicator group (28%). Choosing mild measures for management of population mobility, the accent is usually put on the environmental impact of the trip, safety, moral and physical feelings of a passenger, etc. But the objective weights of indicators found out by the entropy method revealed that care for the trip safety was equal to 5%, awareness of the environmental impact was 4%, and the lowest weight in this case was given to the trip quality: when making a decision on the type of the trip its influence was equal to 2% (Burinskiene, Jauneikaite 2006).

Thus following the results of weights counted for each indicator group using entropy method, the author in collaboration with other VGTU experts rated weights for each particular indicator (see Table 2.2).

Table 2.2. Qualitative and quantitative description of the alternatives

Quantitative and qualitative information pertinent to alternatives								
Criteria describing the alternatives	*****	**Measuring units**	**Weight**	**Compared alternatives**				
				F	**B**	**P**	**C**	**I**
R_{11}	-	min	0.14	1	2	7	3	0
R_{12}	-	min	0.28	120	40	25	20	1
R_{13}	-	min	0.07	1	1.1	1.5	2.5	1
R_{14}	-	min	0.06	0	1	7	10	0
R_{21}	-	Lt	0.15	0	0	5	5	0
R_{22}	-	Lt	0.06	1	2	0	150	30
R_{23}	-	points	0.01	1	2	4	7	0
R_{24}	-	points	0.01	1	3	5	7	1
R_{25}	-	points	0.01	1	1	2	1	1
R_{31}	+	points	0.005	2	2	1	4	5
R_{32}	+	points	0.03	4	3	2	5	5
R_{33}	+	points	0.02	2	2	1	5	5
R_{34}	-	points	0.01	4	4	4	2	1
R_{35}	-	points	0.005	1	1	2	4	5
R_{41}	-	points	0.03	2	3	3	5	0
R_{42}	-	points	0.005	0	0	4	5	0
R_{43}	-	points	0.005	0	0	3	5	0
R_{51}	+	points	0.02	4	4	1	3	5
R_{52}	+	points	0.05	2	1	3	1	5
R_{53}	+	points	0.02	5	4	3	1	5
R_{54}	+	points	0.01	5	5	5	1	5

To have a more precise estimation of the good and bad features of the trip variants being analysed it is necessary to estimate and calculate the influence of all changes on the final result of estimation.

Table 2.3. Interim results of assessment of alternative ways of the trip and determination of their priority and the degree of usefulness

Quantitative and qualitative information pertinent to alternatives								
Criteria describing the alternatives	*****	**Measuring units**	**Weight**	**Compared alternatives**				
				F	**B**	**P**	**C**	**I**
R_{11}	-	min	0.14	0.010769	0.021538	0.075385	0.032308	0
R_{12}	-	min	0.28	0.163107	0.054369	0.033981	0.027184	0.001359
R_{13}	-	min	0.07	0.009859	0.010845	0.014789	0.024648	0.009859
R_{14}	-	min	0.06	0	0.003333	0.023333	0.033333	0
R_{21}	-	Lt.	0.15	0	0	0.075	0.075	0
R_{22}	-	Lt.	0.06	0.000328	0.000656	0	0.04918	0.009836
R_{23}	-	points	0.01	0.000714	0.001429	0.002857	0.005	0
R_{24}	-	points	0.01	0.000588	0.001765	0.002941	0.004118	0.000588
R_{25}	-	points	0.01	0.001667	0.001667	0.003333	0.001667	0.001667
R_{31}	+	points	0.005	0.000714	0.000714	0.000357	0.001429	0.001786
R_{32}	+	points	0.03	0.006316	0.004737	0.003158	0.007895	0.007895
R_{33}	+	points	0.02	0.002667	0.002667	0.001333	0.006667	0.006667
R_{34}	-	points	0.01	0.002667	0.002667	0.002667	0.001333	0.000667
R_{35}	-	points	0.005	0.000385	0.000385	0.000769	0.001538	0.001923
R_{41}	-	points	0.03	0.004615	0.006923	0.006923	0.011538	0
R_{42}	-	points	0.005	0	0	0.002222	0.002778	0
R_{43}	-	points	0.005	0	0	0.001875	0.003125	0
R_{51}	+	points	0.02	0.004706	0.004706	0.001176	0.003529	0.005882
R_{52}	+	points	0.05	0.008333	0.004167	0.0125	0.004167	0.020833
R_{53}	+	points	0.02	0.005556	0.004444	0.003333	0.001111	0.005556
R_{54}	+	points	0.01	0.002381	0.002381	0.002381	0.000476	0.002381
The sums of weighted normalized maximizing (projects 'pluses') indices of the alternative				0.0307	0.0238	0.0242	0.0253	0.051
The sums of weighted normalized minimizing (projects 'minuses') indices of the alternative				0.1947	0.1056	0.2461	0.2727	0.0259
Significance of the alternative				0.1127	0.1404	0.0849	0.0869	0.5863
Priority of the alternative				3	2	5	4	**1**
Utility degree of the alternative, %				19.22	23.95	14.48	14.82	100

That is why the method of multicriteria complex, proportional assessment of projects is applied (Zavadskas, Kaklauskas, Simanauskas 1998). The principle of the method is the following: a standardized matrix is concluded, the sums of minimizing and maximizing indicators that define j variant are calculated, which results in pluses S_{+j} and minuses S_{-j} of each variant. With the values of positive and negative features that define the variants, the relative weight of the variants being compared could be determined, which allows finding rationality of the concerned variants and priorities of choice (see Table 2.3).

Analysis of the results using the method of multicriteria complex for proportional assessment of projects (Zavadskas, Kaklauskas, Simanauskas 1998) allows us to make conclusion that the virtual mobility is the most sustainable way to travel, thus it could be presumed that this way to travel will gradually contribute to the reduction in the significance (and necessity) of making trips on foot.

Afterall the object criterions that have greatest influence on ranking for each alternative were rated. In Table 2.4 recommendations for the improving alternatives sustainability and value in terms of reinforcing indicators are presented:

Table 2.4. Indicators that have greatest influence on ranking of alternatives

Alternative	*Criteria describing the alternative*	*Possible improvement of the analysed criterion in %*	*Possible increase of the value of the alternative in % through increased value of the aforementioned criterion*
F	R_{12}	99.17%	27.7667
	R_{11}	100%	14
B	R_{12}	97.5%	27.3
	R_{52}	400%	20
P	R_{12}	96%	26.88
	R_{21}	100%	15
C	R_{12}	95%	26.6
	R_{52}	400%	20
I	R_{22}	100%	6
	R_{35}	80%	0.4

Goodwin (Litman 2005) noted that price impacts tend to increase over time as consumers have more options (related to increases in real incomes, automobile ownership, and now telecommunications that can substitute for physical travel). In all of cases it is obvious that if time needed for trip (R_{12}) could be optimized it would create great opportunity for physical trips to be more acceptable for users, while for virtual mobility alternative sustainability improvement slight influence could be achieved assuring lesser costs (R_{22}) for Internet or mobile phone user. This supposes, that virtual mobility, which allows to save time and almost doesn't cost progressively will be instrumental in decreasing weight of physical trips (Jauneikaite, Misiunas 2007).

Negative impact of lesser physical activities to one's health (R_{35}) was also assumed as depreciatory virtual mobility indicator. "Technical safety while travelling" (R_{21}) was named as very influencing factor for non-mothoryzed trips, what refers to importance of infrastructure. It could be presumed that due to the available opportunities some working places are established at home. Thus, it could be forecasted that the virtual mobility will rapidly expand and, if this prognosis comes true, it is probable that the physical mobility will decrease and this will result in on lower loads at rush hours. As this trend is seen as a reduced concentration of mobility, it will naturally solve the problem of transport system.

2.3. Status quo data and data analysis principles

Usually, the survey data are studied empirically, i.e. manually or with the help of software by summing up, selecting and sorting data, i.e. the main results are the frequency of one or another indicator in respect of the other, modal distribution of data of the same sort, statistical average of data, etc. This is a sufficient and reliable analysis method for studying the *status quo* of dynamic values or for analyzing the recurrent sequence of analogical data which enables to make an actual forecast (Jauneikaite, Carreno 2009).

However, when analyzing a behaviour of population mobility in order to replace and (or) supplement physical trips with virtual ones such analysis is not feasible as the sufficient sequence of data is not available (Lithuania has no statistical base on population mobility or travels). That's why one of the most challenging tasks for realization of this research was to collect, to recode, to correct necessary data and only then to estimate virtual mobility and possible physical trips substitution.

2.3.1. Data collection

As it was mentioned above, if there are no necessary data and that was the case with particular research, data had to be collected. For this it was necessary to select all the data indicators (common information, social, infrastructural, economical rates, information about citizen's trips and usage of telecommunications). Having so ambiguous need for data, it was very important to choose a proper way of data collecting.

Comparing experience in getting such data in other countries, we see that the main way for doing it are different questionnaires and travel diaries (Burinskiene, Jauneikaite 2005). The approach adopted in similar British project was designed to reflect the complexity of travel behaviour which may influence the impact of policy interventions on trips (EU transport in figures 1999).

There exist not so many ways to analyze trips. As we can see from other literature (Hjorthol 2002, Axhausen *et al.* 2002, Garvill *et al.* 2003, Kenyon 2006) collected for many years in all the world (to obtain such data) only trip diaries and questionnaires were used.

Diary studies have become increasingly popular in the field of transport research, allowing collection of data on the full context of a travel (Axhausen, Wigan 2001). In research practice four diary designs have been primarily used; namely:

- *Travel diaries* collect information solely about the trip (destination, departure and arrival time, mode(s) and so on);
- *Activity diaries* aim to collect information on the contextual factors that have been identified as being important in determining the place of travel in everyday life;
- *Time use diaries* have tended to record only one aspect of travel.
- *Communication diaries* record not only the activity of communication but also the time and mode of communication.

Trip diaries could be used for onetime information or could be extended and used for collecting information about few days, week's processes in ones daily life. Such diaries are called trip journals and could be used for different target groups (e. g. children and their parents (Burinskiene, Jauneikaite 2005). For mobility data research Communication diary type was chosen and adopted for this particular survey.

2.3.2. Mobility research using travel diaries or questionnaires

Summing up, the following surveys were carried out by the author, VGTU (Burinskiene, Jauneikaite 2006) or other statistic researchers:

- Survey of Vilnius residents (2005, sample: 16–74 year old permanent residents of Vilnius (~ 460 000); 2575 respondents were surveyed (RAIT 2005, 2006, 2007).
- Survey of Silale and Silute district residents (2006–2007, a sample of 16–74 year old permanent residents of Silale and Silute district ~70 000); 1200 respondents were surveyed (equally per district).
- Surveys on different residential areas (adults):
  - 2004, sample: parents of pupils from 2 secondary schools (~ 1 900); 481 respondents were surveyed;
  - 2008, sample: 123 residents of Pasilaiciai living district (~ 20 000).
- Students of Vilnius Gediminas Technical University (VGTU):

  - 2004, sample: VGTU students (~ 13 500); 122 who lived outside the campus were surveyed;
  - 2005, sample: VGTU students (~ 13 500); 124 who lived on the campus were surveyed;
  - 2006–2008 students: VGTU students (~ 13 500); 911 were surveyed.
- Pupils of Lazdynai district:
  - 2003, sample: pupils of 5 secondary schools (~ 5 500); 647 respondents were surveyed before organizing mobility campaigns;
  - 2004, sample: pupils of 5 secondary schools (~ 5 500); 616 respondents were surveyed before organizing mobility campaigns;
- Pupils of Širvintos town:
  - 2004, sample: pupils of 2 secondary schools (~ 1 900); 481 respondents were surveyed.

A diary (communication type) for the survey of physical and virtual trips was first developed in 2006. More than 200 students of VGTU filled in the diaries of virtual mobility on different days of the week, indicating the main goals of using the Internet and mobile phones. Respondents also indicated all the trips they made by using different transport mode, duration and purpose of the trips, information about their living place, income and social status.

Preliminary analysis of this data by the authors showed an increasing use of the Internet and a decrease in number of physical trips made, suggesting an association between the two variables, but an inability to establish the cause and effect. To address this key point, the 2006 diary was amended to include a series of questions asking respondents to state if physical trips have been replaced with virtual trips, and if yes, what trips and under what circumstances (see Table 2.5).

Such a diary structure (see Table 2.5) was chosen in order to separate as precisely as possible those virtual activities which have no large influence on physical mobility from the real virtual trips. In this research defined the virtual trip is defined only as activity which with the help of Internet or mobile phone directly replaces physical trip, otherwise this is called the use of Internet or mobile phone and is not further referred as virtual trip.

Analysis of survey results showed the increasing use of Internet and the decreasing physical mobility, however, it gave no answer to the main question "Are physical trips replaced with virtual trips (if yes, what trips and under what circumstances)?" There is always a danger that in attempting to collect data on everything in fact we collect data on very little, since our survey design did not take into consideration many of our participants. Therefore, following the principle of "*communication diaries"* in 2008 our previous diary was supplemented with the question „If You have no access to telecommunications would You do a physical trip?" and with a possibility to point out which transport mode was avoided by the respondent, what would be the distance of the trip and how long would it take to make it.

Table 2.5. Fragment of the diary wording started to be used in 2008

Internet services	**Time taken**	**If You don't have access to telecommunications would You:**	**YES**	**M**	**T**	**D**
Search for information for studies/work		*go to library?*				
Ordering of manufactured goods		*go to shop?*				
Ordering food for home delivery		*go out for eating or shopping?*				
Payment of bills		*go to bank or other place to pay?*				
E-correspondence *…received mail, …sent mail (indicate the number)*		*meet correspondents personally?*				
Mobile phone *(indicate the number) …maid calls,…received calls, …sent SMS, …received SMS*		*meet talkers personally?*				
Socialization on public (readily accessible portals) or private (MSN, ICQ, Skype, etc.) chart-rooms		*meet You chat mates personally?*				
Playing games		*go out for other activities?*				
Downloading movies		*go to cinema or records store?*				
Downloading music		*go to concert or record store?*				
Other (indicate)						

Please indicate the reasons, goals and tasks carried out using telecommunications (Internet and mobile phone) yesterday and time (in minutes) taken for that. Please also point which of your virtual activities would have been replaced with the trip if you have no access to telecommunications (YES column - mark it, if you answer the provided question positively). If you answer that you should replace this activity with the trip, please indicate which transport mode you would use to make that trip (use code from Table 10.a., e. g. taxi – 8 and put into column M,), how long do You think your trip would take (in minutes, put into column T) and approx. distance of the trip (in kilometers km, put into column D.

In contrast to typical practice (virtual trips are divided into three major trip purpose groups: e-work, e-business, e-commerce and e-services, (e. g. The Virtual Mobility Knowledge Base 2008) authors divided the types of virtual trips into 10 classes (see Table 2.5).

2.3.3. Plan for experiment on physical mobility substitution by virtual

As it was reported above, the main technique chosen for research on inhabitants' mobility and especially on physical mobility substitution performing virtual trips was physical statistical survey using communication type diaries. Therefore for performing this survey purposefully strict and concrete experiment plan was needed. The main questions to be answered before starting the survey:

- The target group;
- The time and the place chosen for interviewing;
- The way to collect filled questionnaires;
- The reliable amount of answers needed;
- The continuance of survey;
- The main expectations.

The respondents for survey usually are chosen randomly or the particular group of society is chosen as representative following some criterias, e. g. age, education, work occupation, family commitments, car ownership, living place and etc.

The main criteria influencing person's behaviour (with special attitude to his/her transportation needs) are:

- his/her main occupation and relation among living/working place (far, close – does it force to travel during rush hours?);
- city type (industrial, recreational, students, commercial etc.) and extent;
- existing transport infrastructure all over the city;
- location of living/working place – its accessibility by other than car transport means;
- car/bicycle/mobile phone ownership and Internet access;
- income;
- age;
- gender;
- marital status
- environmental awareness.

In our case a user of urban transport system or (and) telecommunications is almost every single person. Physical activities were analyzed and results published in previous publications of the authors (Burinskiene, Jauneikaite 2005, 2006, 2008). Data concerning information about mobility in Lithuania, Europe and the USA (see ch. 1) showed one and the same tendency – mobility of citizens (number of trips per day for one inhabitant) is normally increasing till a certain age limit (see Fig. 2.2) and later this number of trips per day is decreasing, usually mobility was getting to the pick at the age of 20–30 and reached the 3.5±0.2 trip per day and 1.3±0.2 at the age of 60 and over.

The previous surveys showed that young (aged 16–30 years) (Burinskiene, Jauneikaite 2005, 2006) people are not only the most active IT technology users but also the least mobile group of the society in a sense of transport trips. Decreasing physical mobility was the main factor forcing to choose young people as a target group, as some tendency for them to choose virtual mobility was predicted.

Therefore, **20–25 year old students** were selected for a three-year sociological survey with the aim to evaluate the extent and the importance of virtual mobility within this group. This group was selected not only because they are supposed to have a higher virtual activity (based on the VGTU data in 2008 only every second 39–65 year-old Vilnius City resident used the Internet, whereas, in the same year nearly 95 percent of the students had a possibility to use Internet at home and made on average 2.5 virtual trips per day), but also due to the fact that car ownership and its use is relatively high and increasingly disproportionate among other groups (based on data of 2008 survey 42% of students have an access to private cars and use them as drivers for daily trips).

It was also decided that for comparison purposes the adults should be questioned, their diaries information was expected to be especially useful for the analysis of dependency of population mobility on age.

The time and the geography of survey. There are few main criteria concerning travel research questionnaires distribution among potential interviewees: time (weekdays, weekends, pick time), geography (particular administrative area (e. g. living district in city, different administrative areas (places in different cities, towns) and place of interviewing (random place, interviewees main working (living) place, near target points (e. g. public transport stops if the aspect of research is usage of public transport).

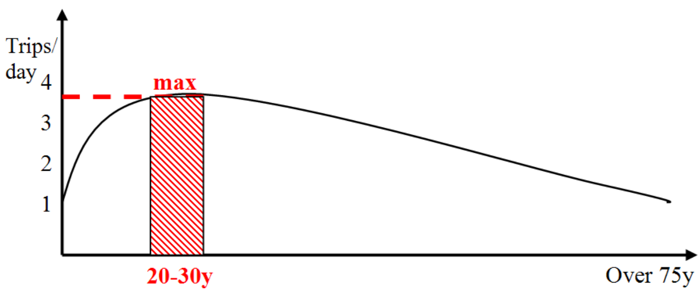


Fig. 2.2. Mobility dependence on age

Having in minds results of surveys done previously (see ch. 2.3.2) it was decided to perform research in **Vilnius city** as it is the most targeting administrative point, at the moment solving different transportation and land use problems as well as relatively the youngest city, having in minds the population of students within the city. To make the survey results as much unbiased as possible specific features of the trips (number and purpose of trips, the selected transport mode, replacement of physical trips with virtual ones and possible reasons) made by the students **living in and off the campus** were studied separately.

For collecting correct information interviews were done in different weekdays.

The way to collect filled questionnaires. According to experience of statistical research companies (RAIT, TNS Gallup), a direct interview is normally being used when reaching interviewees is physically difficult by phone or mail (e-mail) or when questionnaires are relatively complicated to be filled without interviewer's help. Otherwise questionnaires can be distributed among interviewees and let be filled by themselves.

According to this experience the design of travel **diaries was set up in the way that the interviewees could fill it on their own**, providing respectively correct answers. This helped the author and other researchers to obtain a reliable amount of answers by distributing them to the particular number of survey participants.

The reliable amount of answers needed. For estimating the needed sample size for above given accuracy the following formula was used (2.2):

$$n = \frac{t^2 * p * q * N}{\Delta^2 * N + t^2 * p * q}, \tag{2.2}$$

where: $p = q = 0.5$ (likelihood); $t = 2$ (Student's criteria); $\Delta = 0.05$ (size of bias), N – number of whole target group.

As later on the target group was constricted till particular age VGTU students, the necessary amount of respondents needed for survey to be reliable (95% probability and 1.9% error) was estimated (using formula 2.2) as 400 interviewers. But having in mind the specific of research question (usage of virtual trips) it was decided to increase the minimum of answers needed, **thus 1034 respondents were interviewed**.

The continuance of survey. The physical research was continuously held for three years in 2006–2008. Because of diary modification, information about virtual trips was collected only during the last survey in 2008.

The main expectations. One of the main factors for successful research is to define clearly the information from survey needed and possible research results, its dimensions and need for the row of data during few years. The author has decided to collect all possible information allowing to analyse and make assumptions according to the topics listed below:

- changes in research participants mobility and travelling behaviour;
- relations between social features, travelling behaviour and telecommunication using habits;
- tendencies of physical and virtual trips according to the weekday of the and travellers living place;
- substitution of physical trips by virtual ones.

Each of diary question was related somehow to all or at least one of the topics presented above. The research was successful in the terms of data collected. It allowed the author to perform deep analysis, answer all questions raised up at the preparatory stage and after all to draw model of physical trips substitution by virtual trips.

2.3.4. Preparation of obtained mobility data for further use

Normally the obtained data (even if the diary is well designed and interviewees are competent to fill diaries in) are not sufficient to be put directly into database. For this data must be checked and cleaned from logical and random errors.

Axhausen, the author or co-author of a number of papers and studies related with mobility research and especially on methodology of diaries usage suggests (Axhausen, Wigan 2001, Axhausen *et al.* 2002):

- to use logical corrections where it's possible these to use;
- to replace missing values (manually or with the help of statistical software (e. g. SOLAS);
- to call back (if feasible) for clarifying errors and ambiguities.

During the survey of this work the obtained data were "cleaned" (mistakes were eliminated). The most often mistakes indicating distance (m or km), time (min or hours) were found, those were corrected easily, some of the ambiguities occurred (e. g. interviewees indicated the time spent for trips while in the question above, they noted that haven't done any trip that day) so the author corrected them by herself, as respondents were not asked to provide their contacts.

2.3.5. Mobility data basis creation

After data is collected, database must be created. One of the main disadvantages of natural research is difficulties in questioning the respondents (especially by mail or telephone). However, this is probably the smallest problem if compared to difficulties faced by the scientists when creating data monitoring base or selecting software for data analysis. Already in the process of developing a travel diary one should know in what way the data analysis will be carried out, what structure of the data base is the most suitable and what is the most convenient way to transform data from analogue to digital form (Jauneikaite, Carreno 2009). As there are lots of data with different dimensions, database must be designed carefully, values coded (see Fig. 2.3), values of the same group data often are recoded. Database must be designed in such manner that it could be easily transferred to the chosen statistical software environment later on.

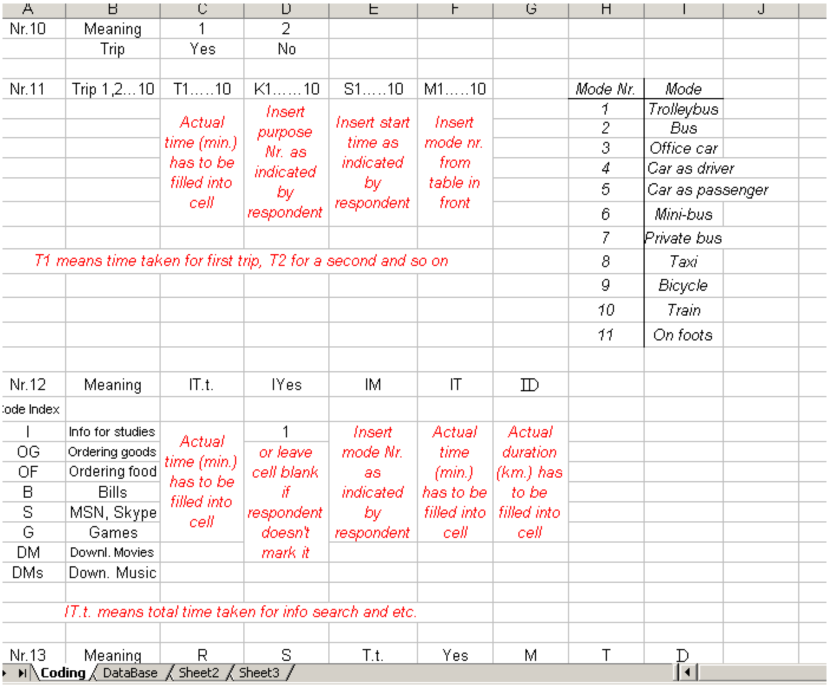


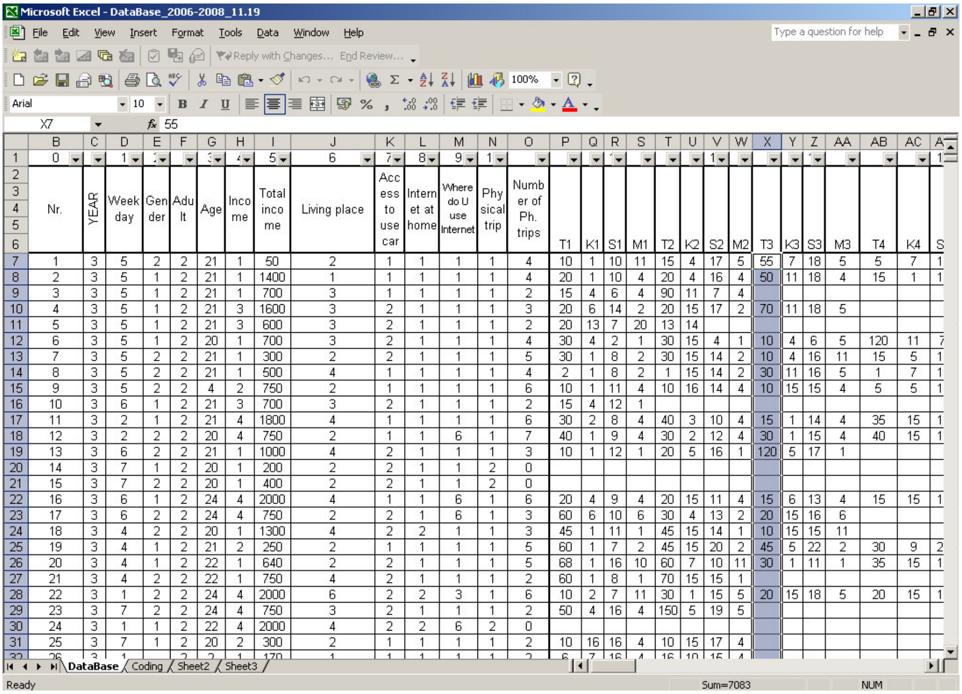
Fig. 2.3. Example of mobility data coding

Data entry is the act of transcribing some form of data into another form, usually a computer program. Forms of data that people might transcribe include handwritten documents, information off spreadsheets from another computer program, sequences of numbers, letters and symbols that build a program, or simple data like names and addresses (Wisegeek 2009).

There are two ways of mobility data storing used in practice. One of them (mostly used) is creation of database in the environment of Microsoft Office. Database created in Microsoft Office is easily transferred to any statistical software if columns and rows are filled properly. Database created in such a way could be used (sorted, selected, summed, presented in graphs and etc.) in both Microsoft Office and statistical software environments.

The other way – to enter data obtained straight to the basis created in statistical software. This works if the aim of the researcher ends up with statistical analysis of data. Presentation of results is not always comfortable, and often the rows or columns of data obtained can't be copied or exported properly to the Microsoft Office.

During the virtual mobility survey the database was transformed several times in order to get it adapted to the selected software, the obtained data was "cleaned" (mistakes were eliminated) and described by their main features (Jauneikaite, Carreno 2009).



Nr.	YEAR	Week day	Gender	Adult	Age	Income	Total income	Living place	Access to use car	Internet at home	Where do U use Internet	Physical trip	Number of Ph. trips	T1	K1	S1	M1	T2	K2	S2	M2	T3	K3	S3	M3	T4	K4	S
1	3	5	2	2	21	1	50	2	1	1	1	1	4	10	1	10	11	15	4	17	5	55	7	18	5	5	7	1
2	3	5	1	2	21	1	1400	1	1	1	1	1	4	20	1	10	4	20	4	16	4	50	11	18	4	15	1	1
3	3	5	1	2	21	1	700	3	1	1	1	1	2	15	4	6	4	90	11	7	4							
4	3	5	1	2	21	3	1600	3	2	1	1	1	3	20	6	14	2	20	15	17	2	70	11	18	5			
5	3	5	1	2	21	3	600	3	2	1	1	1	2	20	13	7	20	13	14									
6	3	5	1	2	20	1	700	3	2	1	1	1	4	30	4	2	1	30	15	4	1	10	4	6	5	120	11	7
7	3	5	2	2	21	1	300	2	2	1	1	1	5	30	1	8	2	30	15	14	2	10	4	16	11	15	5	1
8	3	5	2	2	21	1	500	4	1	1	1	1	4	2	1	8	2	1	15	14	2	30	11	16	5	1	7	1
9	3	5	2	2	4	2	750	2	1	1	1	1	6	10	1	11	4	10	16	14	4	10	15	15	4	5	5	1
10	3	6	1	2	21	3	700	3	2	1	1	1	2	15	4	12	1											
11	3	2	1	2	21	4	1800	4	1	1	1	1	6	30	2	8	4	40	3	10	4	15	1	14	4	35	15	1
12	3	2	2	2	20	4	750	2	1	1	6	1	7	40	1	9	4	30	2	12	4	30	1	15	4	40	15	1
13	3	6	2	2	21	1	1000	4	2	1	1	1	3	10	1	12	1	20	5	16	1	120	5	17	1			
14	3	7	1	2	20	1	200	2	2	1	1	2	0															
15	3	7	2	2	20	1	400	2	2	1	1	2	0															
16	3	6	1	2	24	4	2000	4	1	1	6	1	6	20	4	9	4	20	15	11	4	15	6	13	4	15	15	1
17	3	6	2	2	24	4	750	2	2	1	6	1	3	60	6	10	6	30	4	13	2	20	15	16	6			
18	3	4	2	2	20	1	1300	4	2	2	1	1	3	45	1	11	1	45	15	14	1	10	15	15	11			
19	3	4	1	2	21	2	250	2	1	1	1	1	5	60	1	7	2	45	15	20	2	45	5	22	2	30	9	2
20	3	4	1	2	22	1	640	2	2	1	1	1	5	68	1	16	10	60	7	10	11	30	1	11	1	35	15	1
21	3	4	2	2	22	1	750	4	2	1	1	1	2	60	1	8	1	70	15	15	1							
22	3	1	2	2	24	4	2000	6	2	2	3	1	6	10	2	7	11	30	1	15	5	20	15	18	5	20	15	1
23	3	7	2	2	24	4	750	3	2	1	1	1	2	50	4	16	4	150	5	19	5							
24	3	1	1	2	22	4	2000	4	2	2	6	2	0															
25	3	7	1	2	20	2	300	2	1	1	1	1	2	10	16	16	4	10	15	17	4							

Fig 2.4. Fragment from mobility database created

Mobility data basis was created with Microsoft Excel (see Fig. 2.4) and consisted such data:

- diary filling data (year and weekday);
- personal information (gender, occupation, age, monthly income, living place, access to use car and Internet);
- information about physical trips made previous day (number of trips, duration, purpose, trip starting time and mode);
- information about virtual activities made previous day (time spent and purpose);

- information about virtual trips made previous day (number of virtual trips, information about possibly substituted trip – its duration, purpose and mode).

The final virtual mobility database (year 2006–2008, adults' data included) consisted of 145 columns and 1034 rows. Overall database consists of 149930 data cells.

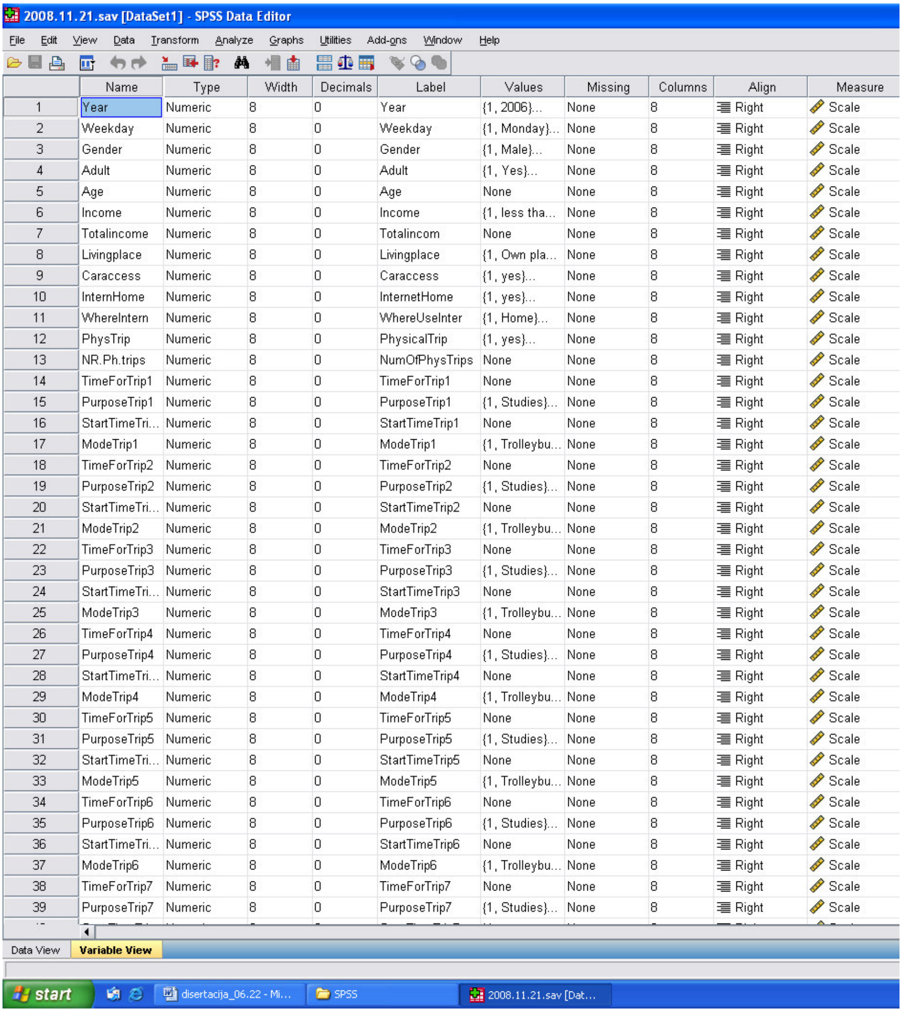
2.4. Software for statistical analysis of mobility data

Having data basis as presented above is already enough to do high quality quantitative analysis of processes we are interested in. The actions such as sorting, selecting, summing, presenting in graphs and etc. can be performed in a handy way, using formulas in Microsoft Excel. But for better analysis accredited statistical software packages are normally used.

SOLAS (Axhausen *et al.* 2009), STOCNET (*Stat. gamma 2009*), Statgraf (*Ddlspot 2009*), MVSP, Oriana, Simstat, Wordstat, XLStat, Data Desk (*Kovcomp 2009*), WinSTAT (*Winstat 2009*) are just a few of worldwide known software systems for the advanced statistical analysis of social networks. Most of them enable to proceed on the same statistical functions. So while looking after software for mobility research a great attention was paid to its possible usage in engineering processes.

For a qualitative analysis of available data the SPSS (Statistical Package for the Social Sciences) software was selected and Clementine's rule induction algorithm was specially adjusted for this software (see chapter below). SPSS can proactively bring data about people's attitudes and preferences into analytical decision making. It broadens perspective on peoples attitudes by tapping into the wealth of knowledge locked in unstructured data with SPSS text analysis products (*Statistical Package for the Social Sciences 2008*).

SPSS Predictive Services helps better manage analytical assets throughout their lifecycle and increase the impact of investment into any infrastructure based on predictive analyses. For example, IAURIF (Institut d'Amènagement et d'Urbanism de la Région d'île-de-France – an organization responsible for a variety of planning and development projects for the île-de-France region (About IAU idF 2008) uses SPSS to predict what mode of transportation Parisians would use. Analyzing and predicting traffic flows and growth is a complex process. For IAURIF, this process started with an existing database of 400,000 records. This data, obtained from a detailed Parisian transport survey, was not originally intended for data mining. IAURIF began by grouping the 200 original fields under general headings, such as place of residence and socioeconomic class. Then analysts selected a representative variable for each group of fields, and ensured that the groups were independent of their effect on transport mode. This important pre-processing enabled IAURIF to pinpoint 26 fields, a core set of relevant variables that would simplify and significantly help the group's data mining efforts.



	Name	Type	Width	Decimals	Label	Values	Missing	Columns	Align	Measure
1	Year	Numeric	8	0	Year	{1, 2006}...	None	8	Right	Scale
2	Weekday	Numeric	8	0	Weekday	{1, Monday}...	None	8	Right	Scale
3	Gender	Numeric	8	0	Gender	{1, Male}...	None	8	Right	Scale
4	Adult	Numeric	8	0	Adult	{1, Yes}...	None	8	Right	Scale
5	Age	Numeric	8	0	Age	None	None	8	Right	Scale
6	Income	Numeric	8	0	Income	{1, less tha...	None	8	Right	Scale
7	Totalincome	Numeric	8	0	Totalincom	None	None	8	Right	Scale
8	Livingplace	Numeric	8	0	Livingplace	{1, Own pla...	None	8	Right	Scale
9	Caraccess	Numeric	8	0	Caraccess	{1, yes}...	None	8	Right	Scale
10	InternHome	Numeric	8	0	InternetHome	{1, yes}...	None	8	Right	Scale
11	WhereIntern	Numeric	8	0	WhereUseInter	{1, Home}...	None	8	Right	Scale
12	PhysTrip	Numeric	8	0	PhysicalTrip	{1, yes}...	None	8	Right	Scale
13	NR.Ph.trips	Numeric	8	0	NumOfPhysTrips	None	None	8	Right	Scale
14	TimeForTrip1	Numeric	8	0	TimeForTrip1	None	None	8	Right	Scale
15	PurposeTrip1	Numeric	8	0	PurposeTrip1	{1, Studies}...	None	8	Right	Scale
16	StartTimeTri...	Numeric	8	0	StartTimeTrip1	None	None	8	Right	Scale
17	ModeTrip1	Numeric	8	0	ModeTrip1	{1, Trolleybu...	None	8	Right	Scale
18	TimeForTrip2	Numeric	8	0	TimeForTrip2	None	None	8	Right	Scale
19	PurposeTrip2	Numeric	8	0	PurposeTrip2	{1, Studies}...	None	8	Right	Scale
20	StartTimeTri...	Numeric	8	0	StartTimeTrip2	None	None	8	Right	Scale
21	ModeTrip2	Numeric	8	0	ModeTrip2	{1, Trolleybu...	None	8	Right	Scale
22	TimeForTrip3	Numeric	8	0	TimeForTrip3	None	None	8	Right	Scale
23	PurposeTrip3	Numeric	8	0	PurposeTrip3	{1, Studies}...	None	8	Right	Scale
24	StartTimeTri...	Numeric	8	0	StartTimeTrip3	None	None	8	Right	Scale
25	ModeTrip3	Numeric	8	0	ModeTrip3	{1, Trolleybu...	None	8	Right	Scale
26	TimeForTrip4	Numeric	8	0	TimeForTrip4	None	None	8	Right	Scale
27	PurposeTrip4	Numeric	8	0	PurposeTrip4	{1, Studies}...	None	8	Right	Scale
28	StartTimeTri...	Numeric	8	0	StartTimeTrip4	None	None	8	Right	Scale
29	ModeTrip4	Numeric	8	0	ModeTrip4	{1, Trolleybu...	None	8	Right	Scale
30	TimeForTrip5	Numeric	8	0	TimeForTrip5	None	None	8	Right	Scale
31	PurposeTrip5	Numeric	8	0	PurposeTrip5	{1, Studies}...	None	8	Right	Scale
32	StartTimeTri...	Numeric	8	0	StartTimeTrip5	None	None	8	Right	Scale
33	ModeTrip5	Numeric	8	0	ModeTrip5	{1, Trolleybu...	None	8	Right	Scale
34	TimeForTrip6	Numeric	8	0	TimeForTrip6	None	None	8	Right	Scale
35	PurposeTrip6	Numeric	8	0	PurposeTrip6	{1, Studies}...	None	8	Right	Scale
36	StartTimeTri...	Numeric	8	0	StartTimeTrip6	None	None	8	Right	Scale
37	ModeTrip6	Numeric	8	0	ModeTrip6	{1, Trolleybu...	None	8	Right	Scale
38	TimeForTrip7	Numeric	8	0	TimeForTrip7	None	None	8	Right	Scale
39	PurposeTrip7	Numeric	8	0	PurposeTrip7	{1, Studies}...	None	8	Right	Scale

Fig. 2.5. Fragment from mobility data basis in SPSS – Variable View

IAURIF analysts then used Clementine's rule induction algorithms, which predicted a three-way variable–whether someone would walk, drive, or take public transportation for a specific journey. Based on experience, IAURIF had first thought that sociological factors, such as income and class combined with the journey's purpose would be the most important causal factors. With help of SPSS and Clementine's rule induction IAURIF uncovered a very significant, and surprising, finding. The most important factors proved to be journey distance and trip time–not those factors the group had predicted on experience alone. In the end, Clementine and this new modelling process increased IAURIF's ability to plan future transportation, as well as increased its credibility. Now IAURIF can more precisely predict future transportation needs, which help better serve Parisians' transportation needs, as well as increase the organization's credibility.

Using SPSS more than 70 built-in functions are available, including:

- Arithmetic functions
- Statistical functions
- Distribution functions
- Logical functions
- Date and time aggregation and extraction functions
- Missing-value functions
- Cross-case functions
- String functions

SPSS also has conditional expressions (also called logical expressions) to apply transformations to selected subsets of cases. A conditional expression returns a value of true, false, or missing for each case.

Data values were coded again after entering it into SPSS Data Editor (Fig 2.5) to have clear results after statistical analysis using the same codes as in main Mobility database (ch. 2.3.5). After that all the values were set out, indicating their name, type, width, label, coded values and measure (scale for all the values.

2.4.1. Main statistic techniques used for statistical mobility data analysis

In terms of selecting a statistical test, the most important question is "what is the main study hypothesis?" It is important to decide *a priori* which hypotheses are confirmatory (that is, are testing some presupposed relationship), and which are exploratory (are suggested by the data). No single study can support a whole series of hypotheses (*Choosing the Right Test, 2009)*.

As it was decided in the stage of research methodology – the deeper analysis of relations between social features, travelling behaviour and telecommunications using habits was performed using Clementine rule algorithm, with special SPSS function (answer tree). For it with after cross tabulation, Chi-Square and T - tests the most significant predictors for analysis were chosen. This conclusion was based on the literature read by the author on the subject (*Campbell, Posock,* *Senn, Gardner, Macbin and oth.)* and discussions with UK researchers' Dr M. Carreno and Prof Dr S. Stradling.

Exclusive statistical analysis wasn't the main aim of the research; the main task was to get necessary results about respondents' mobility, to estimate relation among different variables and to estimate what relations and proportions are objectively significant for the following research. The functions done so far might be divided into two slightly different groups:

- Quantitative basic analysis:
  - Frequency of one or group of variables towards each other;
  - Modal split of the same category data (percentage);
  - Mean and standard variation of variables.
- Quantitative advanced analysis:
  - Cross – tab analysis together with Chi-square tests (Pearson);
  - T-tests;
  - Answer (decision) tree.

Frequency, standard deviation and other basic techniques are widely used in practice and don't require deeper description in this work, so below are described only the main statistical technique used for determining the main factors and predictors important for virtual mobility research.

Cross tabulation is a basic technique for examining the relationship between two categorical variables. For example, using "Car access" category as a row variable and "Necessity to make a virtual trip for paying bills" as a column variable, you can create a two-dimensional cross tabulation that shows the number of males and females in each age category. This technique was used to check and find any significant differences between users according to their social and economical features. Most of the statistical material related to cross-tabulation is covered under Chi-square tests. **Pearson's chi-square** (χ^2) **test** is the best-known of several chi-square tests – statistical procedures whose results are evaluated by reference to the chi-square distribution (its properties were first investigated by Karl Pearson). The chi-square statistics is calculated by finding the difference between each observed and theoretical frequency for each possible outcome, squaring them, dividing each by the theoretical frequency, and taking the sum of the results.

The t-test assesses whether the means of two groups are statistically different from each other. This analysis is appropriate whenever you want to compare the means of two groups, and especially appropriate as the analysis for the post test-only two-group randomized experimental design. In this survey T-tests and Independent Samples Tests were used for determining the relation between two variables who fall into the same category of data with the same feature (e. g. if males and females are statistically different in doing certain number of physical trips).

As the main aim of the research was to try and identify which factors were most important in determining who did virtual trips after reviewing available tests (Chi-Square and T-test) it was decided that a multivariate approach would be best (because of comparing lots of variables simultaneously, rather than lots of individual tests looking at the relationship between two, or three variables- multivariate analysis if more robust and less prone to error, such as Type 1 and Type 2 errors. It was also estimated the nature of the data (which was primarily ordinal), so the author decided to go further with two options: **ordinal regression or Answer Tree**. Basically, they are doing the same thing, although whereas regression explains which factors are the best predictors (e. g. day of week, or gender etc. in explaining virtual trips) it presents this result in a numeric sort of way (e. g. gender accounts for 0.15 of the variance) which is not really a very user friendly way of presenting (or understanding) the results. Whereas **Answer Tree** does the same job, but presents the results in a more user friendly way, in terms of % and etc.

The use of the above-mentioned answer or decision tree is inconceivable without Clementine's rule induction algorithm, which is a comprehensive, integrated toolkit which provides support for data mining in the form of neural network and rule induction learning techniques, passive support in the visualisation, statistical and browsing facilities, and peripheral support for data access and manipulation (Kahabaza, Shearer 1995).

MODEL OF PHYSICAL MOBILITY

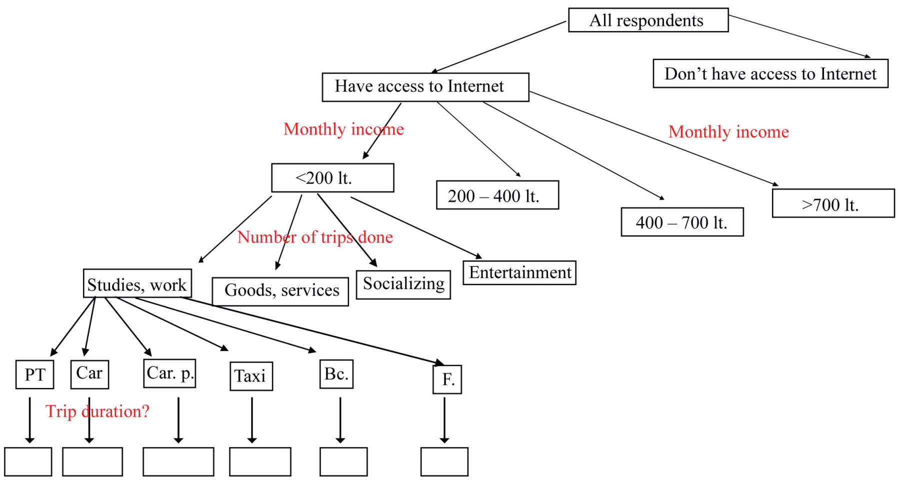


Fig. 2.6. "Decision tree" for physical mobility research

Decision trees fall into the category of data mining tools called classifiers , which are especially useful in differentiating the parts of population (Korrab 1997), like in this research differentiating those groups which are the most likely “to be different” in doing physical or virtual trip (see Fig. 2.6 and 2.7).

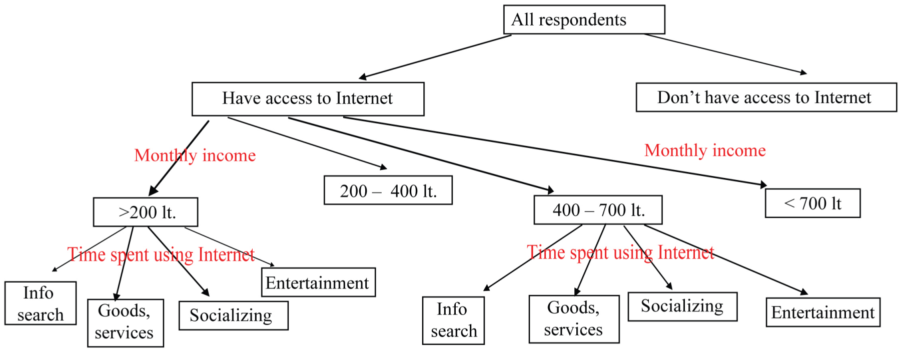


Fig. 2.7. “Decision tree” for virtual mobility research

Answer tree model is especially sensitive to a quantitative expression of data (sample), to data reliability and significance. Without meeting at least one of the mentioned criteria the design of decision (answer) tree model is impossible or the obtained data is not enough to formulate the sufficiently correct conclusions. The aim of analyzing data of mobility diaries with the help of decision (answer) tree model was to check various assumptions about different respondent groups (for example, by a living place), different number of their physical and virtual trips, their purpose, selected transport mode, etc. This model analyzes only the statistically significant $p > 0.05$ and very significant $p > 0.001$ results. Results are presented in a graphical form, in a descending order of significance from statistically the most significant factors on the top to less relevant on the bottom (see results in ch. 3.2.1).

2.5. Theoretical model for virtual mobility research

Systematically working and analyzing people mobility as a subject of a whole urban engineering with the approach of science – the theoretical model for virtual mobility research was created (Fig. 2.8).

For proving predictive hypothesis the authoress had chosen multipurpose complex proportional analysis (created by the VGTU scientists) and determined the most significant factors for choosing trip’ mode. Indicator groups influencing mobility most significantly are these: trip duration (61%) and price (28%), the significance of those criteria proves prediction that virtual mobility, which allows saving time and almost doesn't cost progressively – will be instrumental in decreasing physical trips weight.

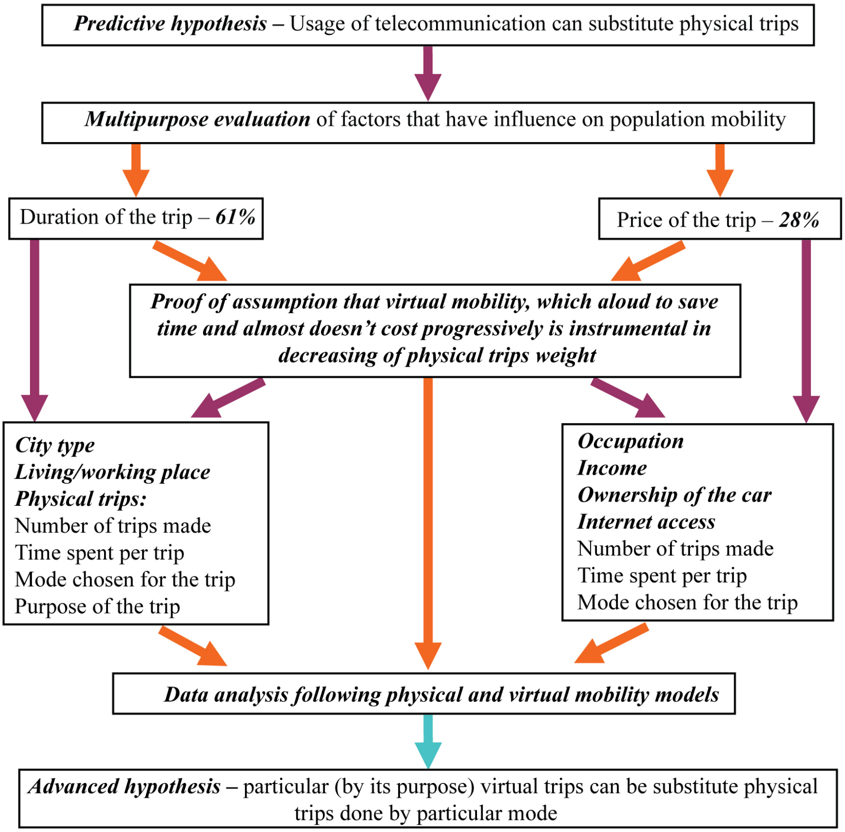


Fig 2.8. The model for virtual mobility research

In order to prove this prediction, a physical research was continuously conducted for three years. The communication diary type was chosen for the survey, the method of "filling in" – the day of the survey respondent was reporting on his mobility on the previous day – i. e. how many, on what purpose, what duration and distance physical trips were done. The similar questions were given about respondents' virtual mobility.

As it is presented in the Fig. 2.8 potentially important variables are divided and analyzed in two groups: so called physicals, which don't really depend on a respondent (type of the city, parameters of obligatory trips and etc.) and so called social – economical factors (income, car ownership, access to Internet and oth).

For a quantitative analysis of available data the SPSS (Statistical Package for the Social Sciences) software was selected and suggested for such research. For reasonable adoption of Clementine's rule induction algorithm "decision trees" for physical and virtual mobility research should be prepared (see examples in Fig. 2.5 and 2.6). Following such sequence it is feasible to succeed necessary results as in this particular case to find out which main factors are mostly influencing the physical and virtual trips and their dependence on each other. Methodical examples of software usage and statistical techniques as well as research results and its interpretation are presented in ch. 3.

2.6. Conclusions of the second chapter

1. Observed decreasing physical mobility was the main factor forcing the author to choose young people as a target group, as some tendency for them to be the most open to virtual mobility was predicted. Therefore, 20–25 year – old students were selected for a three-year sociological survey with the aim to evaluate the extent and the importance of virtual mobility within this group.
2. One of the most challenging tasks for realization of this research was to collect, to recode, to correct necessary data (as such data are not available at the moment) and only then to estimate virtual mobility and possible physical trips substitution. That's why for mobility data research the authoress had chosen *Communication diaries* and successfully adopted for this particular survey. For a qualitative analysis of available data the SPSS (Statistical Package for the Social Sciences) software and the specially adjusted for this software Clementine's rule induction algorithm with Answer Tree were selected.
3. According to multipurpose evaluation done – indicators related to the duration of the trip is the most significant when choosing the type of the trip (the objective weight: 61% of decision depends on the duration of the trip); the second most significant indicators are those related to the price of the trip (28%). Thus predictive hypothesis that virtual mobility enabling to carry out household operations (that do not need long trips in case of physical mobility) should gradually contribute to the reduction in the significance (and necessity) of making physical trips was proved.
4. Systematically working and analyzing people's mobility as a subject of a whole urban engineering with the approach of science – the theoretical model for virtual mobility research was created. This could be used as a background for further researches in Lithuania and mobility data monitoring.

3

Virtual mobility extent, research of its relation with physical mobility

The results published in 2008 (Ubogu 2008) state that 76.7% of the respondents (research was held in Zaria) substitute certain trips in the city, however the author states that it doesn't eliminate urban trips. The aim of this chapter as of the whole research is to estimate the extent of virtual mobility in Lithuania, to calculate trips to be substituted and contradicting to previous conclusions to determine modes, distances and time "saved" substituting physical trips. Only having this data is possible to objectively evaluate and answer the question: "Do and by what extent virtual trips changes physical mobility?"

Based on results of this chapter 2 articles were published (Jauneikaite, 2007; Jauneikaite, Misiunas 2007).

3.1. Changes in mobility research participants travelling behaviour

With a purpose to create the model of physical trips being replaced with virtual ones it is important to define the user and his/her social features and so to presumably determine in which social, environmental and economical circumstances physical trip is most likely replaced with virtual trip. The second aim of this subchapter – to analyze changes in research participants travelling habits and behaviour.

Background information about target group: the age 20–24 y., dominating living place – family house or campus, access to Internet: 2006 – 75%, 2007 – 87%, 2008 – 95%

Women used to be more frequently provided with the Internet connection at home than men (75% (2006) and 77% in 2007). Surprisingly in 2008 this number has been changed, overall (2006–2008), access to the Internet at home had been changed respectively. So we see that general distribution between males and females who have access to the Internet at home have been changing continuously and at the end of the research we can state that the share between different gender representatives having access to the Internet is almost the same (49.2% – females, 50.8% – males) (Table 3.1).

Table 3.1. Cross tabulation results of gender share towards Internet access 2006–2008

Crosstab			
Gender	InternetHome		
	yes	no	Total
Male	445	72	517
Female	447	53	500
Total	892	125	1017

The largest part of "Internauts" live at their parents home or in dormitories where the Internet access makes no additional costs, whereas the largest part of respondents having no Internet live in a rented dwelling where they would have to pay for the Internet connection. The respondents who have no Internet are more mobile than those who have it. Almost 5% of respondents having Internet at home made not a single daily trip, if compared to 1% of respondents having no Internet. The largest part of trips made by the "Internauts" are by passenger car (as drivers or passengers), while more than half of those having no Internet uses the public transport;

3.1.1. Changes in citizens' physical mobility

The main conclusion made from the analysis of physical trips in the period of 2006–2008 is the following: students are not the most mobile target group, they make less trips than the 35 year-old and older respondents (results of adult survey has been also included, see Fig. 3.1) and naturally, mobility of students living in the campus and those who make at least 2 physical trips to come to the educational institution (living off the campus) is different (although analysis didn't name predictor "living place" as significant).

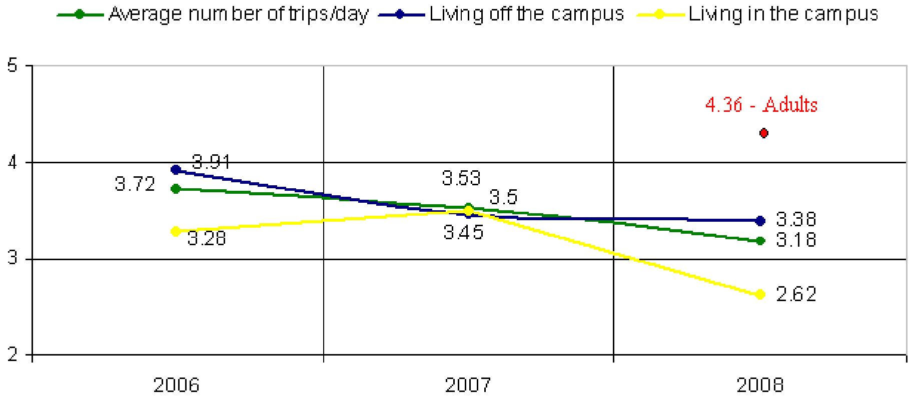


Fig. 3.1. Average number of trips made per day

According to physical trips, identified in the mobility diaries, the modal distribution of trips was defined by their purpose and transport mode in each of research years (see Table. 3.2 and Fig. 3.2).

Table. 3.2. Comparison of students and adults trips by mode (%)

Mode	**2006**	**2007**	**2008**	**Adults**
Trolleybus	27.2	27.7	24.1	14.5
Bus	17.2	19.3	18.5	14.5
Mini-bus	1.5	1.2	0.6	1.9
Private bus	0.5	0	1	0.4
Train	7.1	6.6	0.6	0
PT	**53.5**	**54.8**	**44.8**	**31.3**
Office car	0.6	0	0.9	0.9
Car driver	18.9	18.1	26.2	20.1
Car passenger	12.6	11.4	13.9	8.6
Taxi	0.5	0	0.2	0.2
CAR	**32.6**	**29.5**	**41.2**	**29.8**
Bicycle	-	-	0.2	0
Walking	13.8	15.7	13.7	38.9
Friendly	**13.8**	**15.7**	**13.9**	**38.9**

For comparison, the table concerning information about percentage of respondents who haven't made any trips is presented (Table 3.3)

Table 3.3. Comparison of students and adults who haven't made any trips (%)

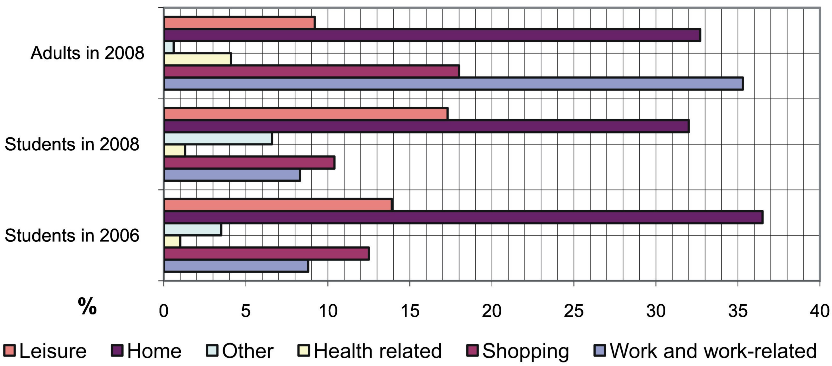
Haven't made any trip	Students in 2006	Students in 2008	Adults in 2008
%	7.6	8.9	-

It is evident that the number of trips that can be replaced with virtual trips has been slightly decreasing, i.e. during two years (data of 2007 is not included) the percentage of work-related trips as well as shopping trips has decreased by 0.5 and 2.1 percent respectively from the total structure, almost by 6 percent from the number of work-related trips and almost by 17 percent from the number of trips made for shopping purposes (Table 3.4). This allows making an assumption that the number of these trips has decreased after they were replaced with virtual trips.

Table 3.4. Comparison 2006-2008 students and adults trips by purpose

Purpose	2006	2007	2008	Adults
Studies	23.6	24.6	23.8	0
Work	5.9	3.0	6.1	29.4
Work related	2.9	3.0	2.2	5.9
Business	**32.4**	**30.6**	**32.1**	**35.3**
Shopping	12.5	15.0	10.4	18.0
Health related	1.0	3.0	1.3	4.1
Kindergarten	0.2	0.6	0.3	0
Other	3.5	1.8	6.6	0.6
Daily issues	**17.2**	**20.4**	**18.6**	**22.7**
Friends	6.6	6.0	4.8	1.1
Sport	2.0	2.4	2.4	0
Active leisure	0.5	1.8	1.5	2.8
Cinema	0.3	0.6	0.9	0
Theatre	0.3	0.6	0.3	0
Restaurants	2.8	3.0	3.4	4.6
Oth.entertainment	1.2	0.6	3.5	0
Garden/forest	0.2	0	0.5	0.7
Leisure	**13.9**	**15**	**17.3**	**9.2**
Home	**36.5**	**34.1**	**32.0**	**32.7**

Figure 3.2 gives the broadened structure of trips made by the respondents per day.



Note: because different target groups had been compared, trips related to studying were excluded from the chart.

Fig. 3.2. Comparison of students and adults trips by purpose

3.1.2. Changes in mobility research participants' habits using telecommunications

In 2006, 75% of respondents had the Internet access at home. In 2007 this proportion has increased up to 87% of respondents and up to 95% in 2008. In 2006 one respondent spent on the average 100 min on the Internet. In 2007 the average time spent on the Internet has grown up to 130 min see Fig. 3.3, Table 3.5.

Evidently, time duration spent on the Internet every day has been growing, especially among the respondents having no direct access to the Internet. In 2007 this duration was on the average 26 longer than in 2006. But in the year 2008 average time spent using Internet decreased to 85 min, although almost everyone had access to Internet, it could be explained by awareness of users and satiation of media. Some other conclusions could be done after looking deeper into 2008 data concerning virtual trips shift by purpose, but not the time used for activities.

When comparing the respondents by their purpose for the use of the Internet, some trends could be singled out:

- between both target sub-groups (those who have access to the Internet and those who don't) time spent for direct work, info search and ordering goods or services over the Internet is not large and by its duration is similar between both those having the Internet access at home and those not having it;
- in 2007, taking into account the increasing time spent on the Internet, the main differences become clear between those having the Internet at home and those not having. Respondents having the Internet at home spend more time for entertainment, whereas those who have no Internet spend more time for the search of information for their studies or work, and this shows the growing trend for the young people to make one transport trip to the

Internet access instead of one (several) trips to achieve the necessary goals without the use of Internet.

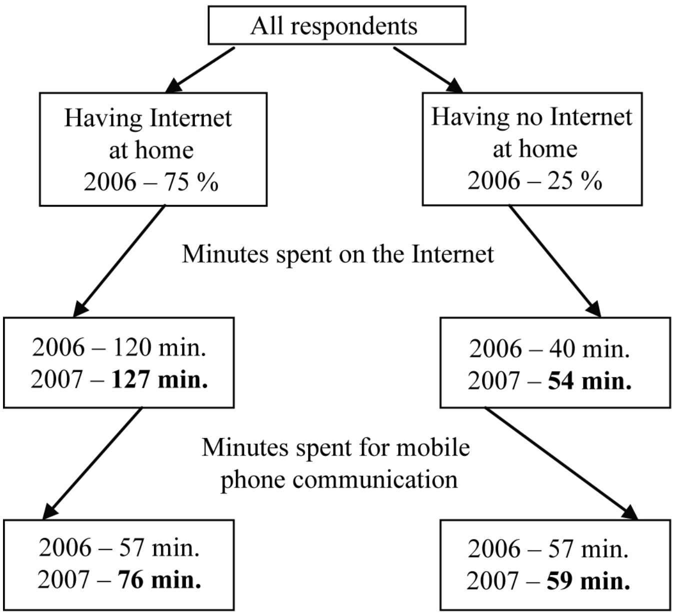


Fig. 3.3. Duration of using the Internet and a mobile phone (2006–2007)

In 2006 one respondent spent about 57 min per day for the mobile phone communication. In 2007 this number has increased up to 70 min per day, but 2008 surveys shows a different shift again – on the average students spend 58 min per day communicating via mobile phone, it might be explained as consequence of higher access and usage of Internet, especially for socializing needs.

Table 3.5. Time spent on the Internet according to the purpose of its use

2006							
Having Internet at home				Having no Internet at home			
Info search	Goods, services	Commu-nication	Entertain-ment	Info search	Goods, services	Commu-nication	Info search
24 min	2 min	53 min	41 min	19 min	1 min	14 min	6 min
2007							
Info search	Goods, services	Commu-nicat.	Info search	Info search	Goods, services	Commu-nicat.	Info search
18 min	1 min	53 min	55 min	39 min	0 min	12 min	3 min

A larger increase in the duration of telephone calls and sending SMS was observed between those having the Internet access – in 2007 this proportion has increased by 25% compared to 2006.

As it is obvious from the results presented above, these were not sufficient for confirming or denying hypothesis of trips substitution with telecommunications help. Therefore further analysis on time spent using Internet shift wasn't done, as in 2008 more than 500 respondents provided information about virtual trips.

In order to check the above assumptions the analysis of virtual trips was carried out by their purpose (see Fig. 3.4) and by the replaced transport mode (see ch. 3.4).

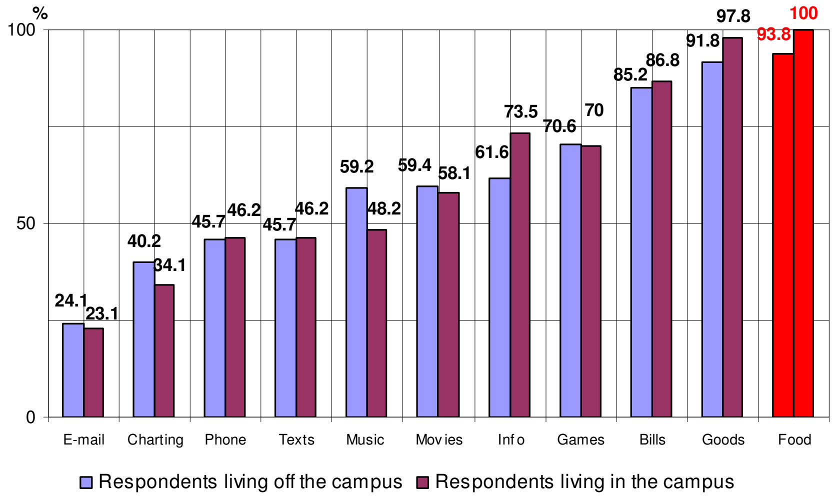


Fig. 3.4. Finding out whether virtual activity replaced a physical trip?

One can see that ordering food and other goods replaces physical trips by almost 100 percent. One third of the respondents indicated in their travel diaries that a possibility to buy on the Internet "saved" at least one physical trip during the day; they also pointed out the transport mode and the distance they would travel (see ch. 3.4).

3.2. Deeper analysis of relations between social features, travelling behaviour and telecommunication using habits

First of all in order to examine the obtained data and dependence of each variable on the other – the following tests were carried out:

a) cross tabulation together with Chi-Square test (see ch. 2.41 and ch. 3);
b) t-test (see ch. 2.4.1);
c) answer-tree (see ch. 2.4.1 and 3.2.1).

3.2.1. The main predictors as to whether and why respondents make trip(s)

Below are named variables (statistical features are presented only near variables that were found as significant for this research) which were presumed to be the main possible predictors for the questions why, who and whether does virtual or physical trips:

- the number of performed trips (single trips and their groups (1–3) (or) and (4–10);
- **year of research (χ^2 (1, N = 690) = 8.84, $p > 0.05$);**
- living place;
- **weekday** (χ^2 (1, N = 899) = 27.58, $p > 0.001$), (χ^2 (1, N = 654) = 203.86, $p > 0.001$);
- **age** (χ^2 (1, N = 815) = 10.36, $p > 0.001$), (χ^2 (1, N = 529) = 6.1, $p > 0.05$);
- access to Internet;
- car ownership or access to use it.

In all the cases, for performing the **chi-square test**, the necessary data (group of variables) were divided into k bins and the test statistic is defined as:

$$\chi^2 = \frac{\sum_{i=1}^{k}(O_i - E_i)^2}{E_i}, \tag{3.1}$$

where O_i is the observed frequency for bin i and E_i is the expected frequency for bin i.

The expected frequency was calculated by:

$$E_i = N(F(Y_u) - F(Y_l)). \tag{3.2}$$

Where F is the cumulative Distribution function for the distribution being tested, Y_u is the upper limit for class i, Y_l is the lower limit for class i, and N is the sample size.

Therefore, the hypothesis that the data are from a population with the specified distribution is rejected if

$$\chi^2 > \chi^2_{(\alpha,k-c)}. \tag{3.3}$$

Where $\chi^2_{(\alpha,k-c)}$ is the chi-square percent point function with *k* - *c* degrees of freedom and a significance level of α.

For example, testing dependence of physical trips on weekday, the following results were got (Table 3.6). Here we can see that the habit to do physical trips depends on the weekday, so χ^2 (1, *N* = 551) = 34.51, $p < 0.001$.

Table 3.6. PhysicalTrip * Weekday Chi-Square Tests

Tests	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	34.506(a)	6	0.000
Likelihood Ratio	30.806	6	0.000
Linear-by-Linear Association	4.266	1	0.039
N of Valid Cases	551		

All the results important for research are presented below in chapter 3 and it was performed following the above described manner.

The formula for the **t-test** is a ratio. The formula for t-test (3.4) shows the difference between the two means or averages and measures of the variability or dispersion of the scores (in this case example of testing if gender is significant for the number of trips done was presented).

$$t - value = \frac{difference\_between\_group\_means}{\text{var}iability\_of\_groups} = \frac{X_T - X_C}{SE(X_T - X_C)}. \quad (3.4)$$

The top part of the formula is easy to compute - just find the difference between the means (e. g. in this research the case with the number of females and males). The bottom part is called the **standard error of the difference**. To compute it, SPSS “had to take” the variance for each group and divide it by the number of people in that group. Then these two values were added and then their square root taken. The specific formula for the Standard error of the difference between the means is given (3.5) below.

$$SE(X_T - X_C) = \sqrt{\frac{\text{var}_T}{n_T} + \frac{\text{var}_C}{n_C}}. \quad (3.5)$$

Variance is simply the square of the standard deviation, so the final formula (3.6) for the t-test is:

$$t = \frac{X_T - X_C}{\sqrt{\dfrac{\mathrm{var}_T}{n_T} + \dfrac{\mathrm{var}_C}{n_C}}}\,. \tag{3.6}$$

The t-value will be positive **if** the first mean is larger than the second and negative if it is smaller. In particular example (see Tables 3.7, 3.8, 3.9) the t-values were: males t(493) = –1.322, p>0.001 (p = 0.187) and females t(468) = –1.321, p>0.001 (p = 0.187). In this case t-value is negative, as first meaning is smaller. In such way all T-tests for above listed variables were done, but no significance differences among them were found.

Table 3.7. T- Test: Gender's significance for the number of trips done

T-Test

[DataSet1] H:\disertacija\SPSS\2008.11.21.sav

Group Statistics

	Gender	N	Mean	Std. Deviation	Std. Error Mean
NumOfPhysTrips	Male	493	3.66	1.598	.072
	Female	468	3.79	1.630	.075

Table 3.8. Independent Samples Test: Gender's significance for the number of trips done

		Levene's Test for Equality of Variances	
		F	Sig.
NumOfPhysTrips	Equal variances assumed	.080	.777
	Equal variances not assumed		

Table 3.9. Independent Samples Test: Gender's significance for the number of trips done

		t-test for Equality of Means			
		t	df	Sig. (2-tailed)	Mean Difference
NumOfPhysTrips	Equal variances assumed	-1.322	959	.187	-.138
	Equal variances not assumed	-1.321	954.130	.187	-.138

As above described techniques (Chi-Square tests and T-tests) haven't provided results significant for this research, the printouts of analysis are presented in appendices. After first experiments predictors "car access", "total income (recoded)" or "living place" (recoded) were excluded as it haven't provided any significant means.

Thus for answer tree analysis four predictors "dayband", "ageband", gender and "access to Internet" were used (because most of respondents have access to Internet – this feature wasn't estimated as significant for research, but still was used further as possible predictor by decision of authoress and researches in charge).

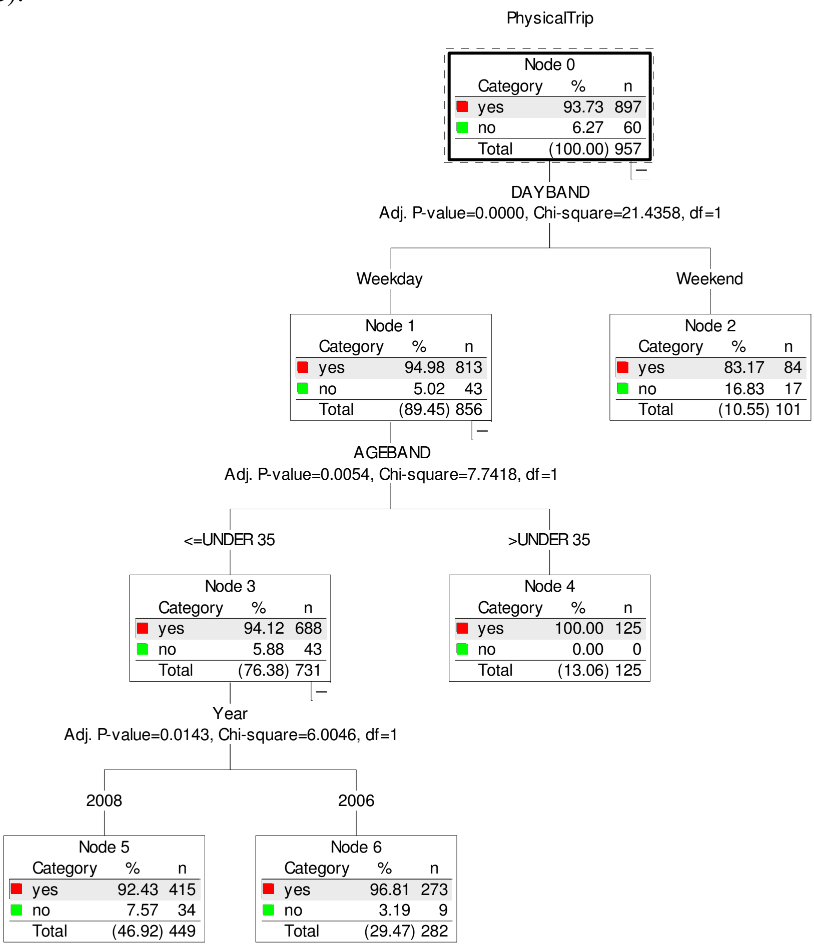


Fig. 3.5. Answer Tree Model: whether a physical trip was made (all years)

A note: answer tree is not a chi square analysis per se, it is a multivariate analytical technique but due to the nature of the variables that the author was examining (ordinal), it uses the chi squared statistics to explain statistical differences). Here dayband and ageband mean recoded groups of similar value data, like "dayband" (all working days or both weekend days), ageband – actual age entered to the databae was recoded into groups (under 35 and over 35).

The main predictor determining whether a physical trip was made (or not) related to the day or week, with significantly more trips being made on weekdays ($\chi^2(1, N = 957) = 21.44$, $p < 0.001$)- i. e. 95% of people reported making a weekday trip compared to 83% on weekends (Fig. 3.5).

Whether a weekday trip was made (or not) was also dependant on respondents age ($\chi^2(1, N = 856) = 7.74$, $p < 0.01$), with all (100%) over 35's reporting making a weekday trip, compared to 94% of under 35's.

For under 35's who made a weekday trip, significantly more people made trips in 2008 ($\chi^2(1, N = 574) = 10.06$, $p < 0.01$, Fig. 3.6) compared to 2006 (Fig. 3.7).

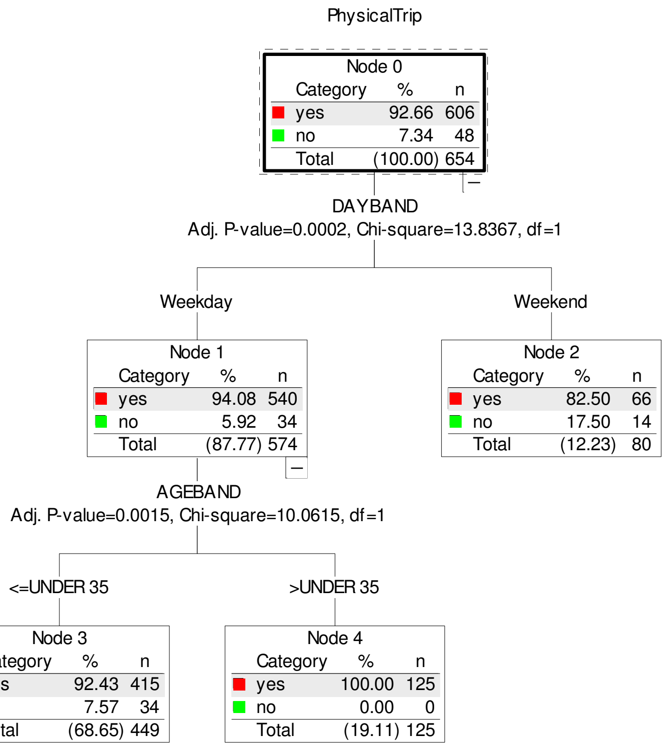


Fig. 3.6. Answer Tree Model: whether a physical trip was made (2008)

Analyzing number of trips done, predictors were reclassified again into two groups- 1–3 trips and 3+ trips. The same predictors: gender, age, weekday and whether respondents have Internet at home or not were used. For this analysis all data of 2006 – 2008 was taken into account, but were selected only those cases where respondents made at least one trip (N = 899).

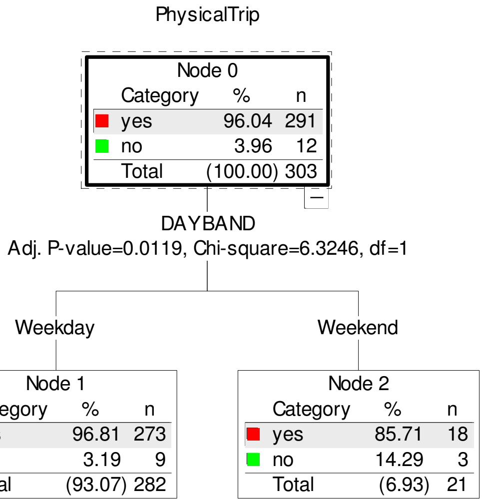


Fig. 3.7. Answer Tree Model: whether a physical trip was made (2006)

The main predictor determining the number of trips made (1-3 trips or 4+) was related to the day of week, with those people making weekday trips significantly more likely to report making 4 or more trips ((χ^2 (1, N = 899) = 27.58, $p <$ 0.001) compared to those making trips on weekends (fig. 3.8).

For those making weekday trips, over 35's were significantly more likely to report making 4 or more trips (χ^2 (1, N = 815) = 10.36, p < 0.01) compared to under 35's.

For under 35's making weekend trips, people in 2006 were significantly more likely to report making more trips (4+), compare to those in 2008 ((χ^2 (1, N = 690) = 8.84, p < 0.01), which proved again prediction that young peoples' mobility is getting less.

After first experiments (chi-square and t-tests) predictors "car access", "total income (recoded)" or "living place" (recoded) were excluded as it haven't provided any significant means. Therefore, for virtual mobility answer tree the same predictors "dayband", "ageband", gender and "access to Internet" were chosen. Here, both dayband and ageband means recoded groups of similar value data, like "dayband" (all working days or both weekend days), ageband – actual age entered to the database was recoded into groups (under 35 and over 35).

The main predictor as to whether respondents made a virtual trip or not, concerned their age, with under 35's significantly more likely to have made a virtual trip (Fig. 3.8) (χ^2(1, N = 654) = 203.86, p < 0.001).

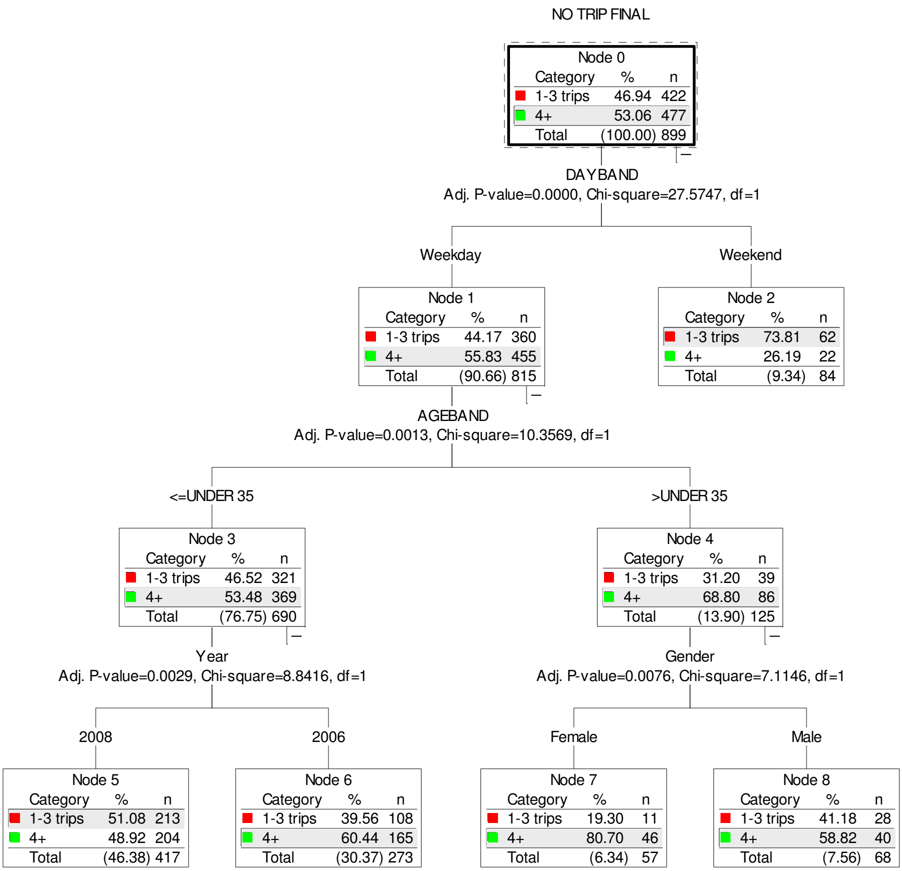


Fig. 3.8. Answer Tree Model: what is important for number of trips (2006–2008)

The number of under 35's who made trips was also dependant on the day of week, with significantly more people reporting making virtual trips on weekdays ($\chi^2(1, N = 529) = 6.05, p < 0.05$), compared to weekends.

Initial data and answer tree analysis (whole ch. 3.2.1 results) rather confirmed than denied the raised hypothesis. It absolutely confirmed the authors' prediction and choice for the target group as more open to virtual mobility, and happily didn't show any significant results as virtual mobility dependence on economical or social status, this allows to continue research and to predict that results are adoptable not only for the target group but for the most of city residents.

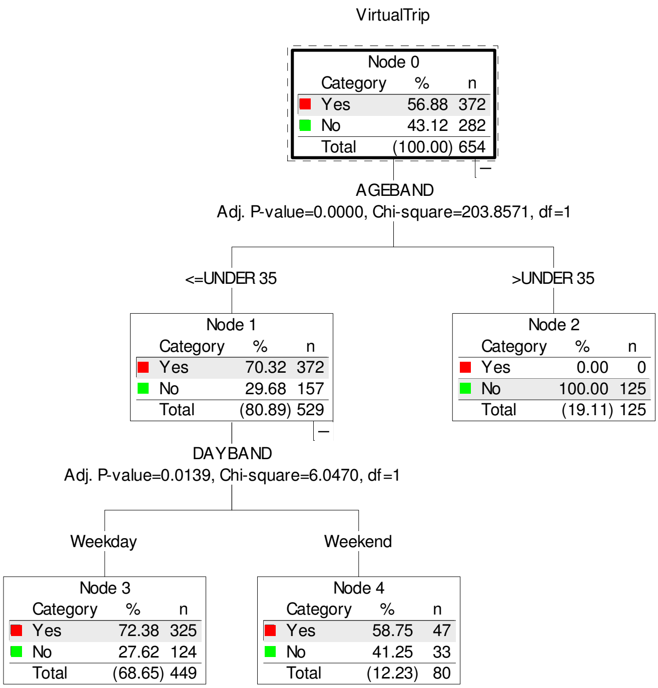


Fig. 3.9. Answer Tree Model: whether a virtual trip was made (2008)

3.3. Tendencies of physical and virtual trips according to the day of the week and travellers' living place

Taking into consideration the fact that physical and virtual trips as well as their number were most significantly influenced by the weekday, an additional comparable analysis was made (see ch. 3.31) in order to find out the relation between physical and virtual trips, i. e. to confirm or to deny the earlier made assumption that virtual trips can replace physical trips and thus to reduce the overall physical mobility (Jauneikaite, Carreno 2009). Also during the primary analysis it was observed, that changes between respondents living in or out off student campus are noticeable (Burinskiene, Jauneikaite 2006, Jauneikaite, Carreno 2009), that's why it was decided to perform a deeper analysis on both of mentioned criteria – day of the week and living place (see ch. 3.3.2).

3.3.1. Virtual and physical trips' dependence on the week day

For objective estimation of physical and virtual trips (whether they had been done and their number) dependence on weekday additional Chi-Square Tests were performed. As we see from results presented in the Table 3.10 and Table 3.11 physical trips significantly depends on weekday ($\chi^2(1, N = 551) = 34.51$, $p < 0.001$).

Table 3.10. PhysicalTrip * Weekday Crosstabulation

Variables		Weekday							Total
		Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	
PhysicalTrip	yes Count	60	103	69	152	43	33	41	501
	% within PhysicalTrip	12.0	20.6	13.8	30.3	8.6	6.6	8.2	100.0
	% within Weekday	88.2	92.0	92.0	96.2	89.6	100.0	71.9	90.9
	% of Total	10.9	18.7	12.5	27.6	7.8	6.0	7.4	90.9
	no Count	8	9	6	6	5	0	16	50
	% within PhysicalTrip	16.0	18.0	12.0	12.0	10.0	0.0	32.0	100.0
	% within Weekday	11.8	8.0	8.0	3.8	10.4	0.0	28.1	9.1
	% of Total	1.5	1.6	1.1	1.1	0.9	0.0	2.9	9.1
Total	Count	68	112	75	158	48	33	57	551
	% within PhysicalTrip	12.3	20.3	13.6	28.7	8.7	6.0	10.3	100.0
	% within Weekday	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	% of Total	12.3%	20.3	13.6	28.7	8.7	6.0	10.3	100.0

Table 3.11. PhysicalTrip * Weekday: Chi-Square Test

Tests	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	34.506(a)	6	0.000
Likelihood Ratio	30.806	6	0.000
Linear-by-Linear Association	4.266	1	0.039
N of Valid Cases	551		

As we see from the results presented in Table 3.12 and Table 3.13, virtual trips also significantly depends on weekday ($\chi^2(1, N = 551) = 16.02$, $p < 0.05$).

Table 3.12. VirtualTrip * Weekday Crosstabulation

Variables			Weekday							To-tal
			Mon-day	Tues day	Wedn esday	Thur sday	Fri-day	Satur day	Sun-day	
Virtual-Trip	Did at least one		42	81	61	111	37	20	31	383
		% within VirtualTrip	11.0	21.1	15.9	29.0	9.7	5.2	8.1	100
		% within Weekday	61.8	72.3	81.3	70.3	77.1	60.6	54.4	69
		% of Total	7.6	14.7	11.1	20.1	6.7	3.6	5.6	69.5
	Didn't do any		26	31	14	47	11	13	26	168
		% within VirtualTrip	15.5	18.5	8.3	28.0	6.5	7.7	15.5	100
		% within Weekday	38.2	27.7	18.7	29.7	22.9	39.4	45.6	30.5
		% of Total	4.7	5.6	2.5	8.5	2.0	2.4	4.7	30.5
Total		Count	68	112	75	158	48	33	57	551
		% within VirtualTrip	12.3	20.3	13.6	28.7	8.7	6.0	10.3	100
		% within Weekday	100	100	100	100	100	100	100	100
		% of Total	12.3	20.3	13.6	28.7	8.7	6.0	10.3	100

Table 3.13. VirtualTrip * Weekday: Chi-Square Test

Tests	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	16.016(a)	6	0.014
Likelihood Ratio	16.023	6	0.014
Linear-by-Linear Association	2.040	1	0.153
N of Valid Cases	551		

Initial data neither denied nor confirmed the raised hypothesis. Evidently, with regard to physical as well as virtual trips the respondents are mostly mobile in the middle of the week and the least mobile in the beginning of the week and on Sunday (Table 3.10, 3.12, 3.14). However, statistics on the trips at the end of the week shows that e. g. on Friday when the respondents are less mobile (almost 11 percent of respondents make no trip at all) virtual mobility reaches the peak, if compared to other days of the week (only on Wednesday at least one virtual trip is made by more than 4 percent respondents). And on the contrary – on Saturday when all the respondents make at least one physical trip (the average – 3.03 trips per day) virtual trip is made only by 60 percent of respondents (the average of the week‘s mobility – 68.3 percent), the average of trips decreases up to 2.03 (if compared to the peak – 3.21 and the average – 2.44). This suggests a one more assumption – part of physical as well as virtual trips (according to their purpose – household, work-related trips) are unchangeable and must be made irrespective of theoretically influencing outside factors (e. g. if the employer disagree with your working at home – you must make at least two work-related trips per day).

Table 3.14. Physical and virtual mobility during a week (Jauneikaite, Carreno 2009)

Weekday	Physical Trips		Virtual Trips	
	Made at least one trip, %	**Average number of trips made**	**Made at least one trip**	**Average number of trips made**
Monday	88.2	2.56	61.8	2.09
Tuesday	92.0	3.69	72.3	2.58
Wednesday	92.0	3.07	81.3	3.21
Thursday	96.2	3.73	70.3	2.61
Friday	89.6	3.19	77.1	2.6
Saturday	100	3.03	60.6	2.03
Sunday	71.9	1.67	54.4	1.98
Boundaries	71.9 ± 100	1.67 ± 3.73	54.4 ± 81.3	1.98 ± 3.21
Average	90.0	2.46	68.3	2.44

Note: Red numbers refer to the values higher than a statistical average, blue numbers – to the lower values.

However, if the resident has a possibility to choose the mode for his trip (e. g. has an Internet access and also a possibility to go by one or another transport mode and is not under obligation to anybody about a selection of his trip) – a certain mode of his physical trips can and is replaced with virtual trips. Therefore, an additional analysis was carried out to study the purpose and the transport mode the physical trips are made and to find out which of them could be replaced with virtual trips and which transport modes would be replaced (see chapter 3.4.1).

3.3.2. Virtual and physical trips' dependence on the living place

Research on students' mobility and its difference according to their living place (out or in a campus) was started already in 2005 (Burinskiene, Jauneikaite 2006). First of all, differences in choosing the main mode for trips was noticed (see Table 3.15).

The public transport is usually chosen by students who live close to the University; such students cover short distances usually on foot and the public transport is chosen for the remaining part of trips (52% of all trips). Students living at a larger distance from the university usually choose a car and usually drive it themselves (37%).

Table 3.15. The prevailing vehicle for the major trips (2005)

Vehicle	Students of Vilnius, %	
	Living outside the campus	Living on the campus
Public transport	47	**52**
On foot	9	38
By car (driver)	**37**	5
By car (passenger)	7	5
By bicycle	n/a	n/a

The analysis revealed that a very limited number of trips to university, school or other objects of attraction is made by bicycle and the reasons for this were found out. For pupils and their parents the main reason for not riding a bicycle was the fact that safety is not guaranteed (due to the absence of cycle tracks and bicycle parking lots); while students said that their objects of attraction were too far to be reached by bicycle and that due to the absence of cycle tracks it was not safe to ride along streets with heavy traffic. Therefore, having in mind that such a small part of trips is made by bicycle and knowing the reasons for that, before choosing measures to raise awareness it is necessary to find out how indispensable they are. Maybe for the chosen target groups it is sufficient to correctly choose objects of physical infrastructure? (see Table 3.16 and suggestions in ch. 4).

Table 3.16. Wish to ride a bicycle when favourable conditions are created (2005)

Position of a respondent	Students of Vilnius, %	
	Living outside the campus	Living on the campus
Would ride a bicycle	65	78
Would not ride a bicycle	35	22

When we mark the place of activities or staying as Ai (i is the index defining the type of activities) and movement as an arrow, then the model of movement frequency could be illustrated as follows (3.7):

$$A_{i1} \rightarrow A_{i2} \rightarrow ... \rightarrow A_{in} . \quad (3.7)$$

In Table 3.17 the model of 2005 respondents' mobility movement is presented.

In 2005 Students did not make trips every day (especially those who live outside the campus). Students who live outside the campus single out the fact that they have only one trip per day (61% of students); so the author at that time already predicted that this might have something to do with virtual possibilities to meet their daily needs.

Table 3.17. Cycles of respondents' movement

Model of movement	Students of Vilnius	
	Living outside the campus	Living on the campus
No trips	**7%**	**5%**
$A_1 \rightarrow A_i \rightarrow A_1$	**61%**	42%
$A_1 \rightarrow 2A_i \rightarrow A_1$	25%	21%
$A_1 \rightarrow 3A_i \rightarrow A_1$	5%	26%
$A_1 \rightarrow 4A_i \rightarrow A_1$	2%	6%

where: A_1 is home, $n*A_i$ is another goal of the trip multiplied by n (the number of r trips).

Later on (2006–2008) new mobility data was collected and tested using Chi-square and T-tests. The living place wasn't identified as a very significant predictor for pupils to make or not to a certain number of physical or (and) virtual trips. Although by the initiative of the author, out of all the data were selected only cases were respondents clearly indicated their living place and two bands were done – "in" and "off" campus.

First of all was tested if respondents' decision not to make any trip is significantly influenced by one's living place. The answer was 'yes' - off campus residents are significantly more active ($\chi^2(1, N = 875) = 7.15, p < 0.01$).

Later on it was tested if respondents' decision to make certain number of trips is significantly influenced by one's living place. The answer was 'yes' – off campus residents are significantly more active and make more trips per day ($\chi^2(1, N = 817) = 12.77, p < 0.01$).

Statistical rate "Mean" was counted for indicating the average of the number of daily trips (2006–2008) and compared with the mean of adults number of trips (Standard deviation isn't calculated and presented). Results show (Table 3.18) that respondents living in the campus make on the average 0.45 trips less than those who are living outside the campus.

If to compare the respondents' access to the Internet, we can see that in both groups access was growing yearly although those who are living in the campus are connected to the Internet with a higher rate and make on the average 0.4 more virtual trips per day (Table 3.19)

Table 3.18. Respondents' mobility (nr.trips/day) 2006–2008

PHYSICAL	AVERAGE TRIPS	OFF CAMPUS	IN CAMPUS
2006	3.72	3.91	3.28
2007	3.53	3.45	3.5
2008	3.18	3.38	2.62
ADULTS	4.36		

Table 3.19. Access to Internet 2006 -2008

ACCESS	AVERAGE ACCESS	OFF CAMPUS	IN CAMPUS
2006	75%	69.3	91.5
2007	85.1%	80.6	100
2008	94.9%	93.9	98.5
ADULTS	87.6%		
VIRTUAL	AV. TRIPS	OFF CAMPUS	IN CAMPUS
2008	2.52	2.41	2.92

PT and CAR trips are decreasing/increasing in both off and in campus respondents' trips. Though it is necessary to pay attention to the fact that only 31.7% (in 2008) of students who are living in campus trips are made by car (comparing with shift of 43.3% among respondents living off campus). But a much more important finding, presented in the Table 3.19, is the rate of changes among same users in three years, which shows a higher level of car trips usage increasing among respondents living in campus. Here the rate is counted manually for example if e. g. the usage of PT among respondents living off campus in 2006 = 1, than the usage of PT in 2008 = 0.85 and the rate shows clearly a decrease in PT usage.

Table 3.20. Comparison of mobility living off and in campus by mode (2006–2008)

Mode	***2006***		***2007***		***2008***	
	Off	***In***	***Off***	***In***	***Off***	***In***
Trolleybus	27.5	27.5	29.9	18.4	23.7	26.5
Bus	19.1	11.5	17.1	12.2	19.6	13.3
Mini – bus	0.7	0	1.7	0	0.7	0
Private bus	0.4	7.8	0	0	1.2	0.3
Train	6.1	11.2	6.0	8.2	0.7	0.3
PT	**53.8**	**58**	**54.7**	**38.8**	**45.9**	**40.4**
Rate of changes (times per 3 year)					**0.85**	**0.7**
Office car	0.9	0	0	0	0.9	0.3
Car driver	22.2	7.8	21.4	10.2	28.6	16.3
Car passenger	13.1	11.2	14.5	24.5	13.7	14.5
Taxi	0.5	0.7	0	0	0.1	0.6
CAR	**36.7**	**19.7**	**35.9**	**34.7**	**43.3**	**31.7**
Rate of changes (times per 3 year)					**1.18**	**1.61**
Bicycle	0	0	0	0	0.7	0.3
Walking	9.5	29.0	9.4	26.5	10.5	27.7
Friendly	**9.5**	**29.0**	**9.4**	**26.5**	**11.2**	**28.0**
Rate of changes (times per 3 year)					**1.18**	**0.97**

The biggest and mostly confusing rate of changes is accounted for CAR usage – it is decreasing among both groups of respondents and mostly confusing is the fact that CAR usage among respondents living in campus grew up 1.61 times. Fortunately campus residents are making much more trips by foot as it is convenient having in mind they studying infrastructure being laid down close to their living place and still are keeping on high rate of public transport usage.

All above described and in Table 3.20 presented results proves again prediction that such mobility and behaviour of campus residents is highly influenced with social and transport infrastructure provided in their living place.

Living in campus are making more of their trips for daily issues – in average they make 28.4% more such trips than those who are living off campus and that could be assumed as lack of social infrastructure (Table 3.21). The number of leisure and entertainment trips is also higher among in campus residents – 19.8% of all trips comparing with 16.3% (off campus residents).

Table 3.21. Comparison of mobility living off and in campus by purpose (2006–2008)

Purpose	***2006***		***2007***		***2008***	
	Off	***In***	***Off***	***In***	***Off***	***In***
Studies	24.6	20.4	26.9	18.4	25.7	16.5
Work	5.6	5.9	3.7	2.0	6.1	5.0
Work related	2.3	5.2	3.7	2.0	2.6	0.9
Business	**32.5**	**31.5**	**34.3**	**22.4**	**34.4**	**22.4**
Shopping	12.2	13.8	13.9	16.3	8.8	16.8
Health related	1.1	0.4	1.9	6.1	1.3	1.5
Kindergarten	0.1	0	0.9	0	0.1	0.9
Other	3.8	3.0	2.8	0	6.0	9.7
Purpose	***2006***		***2007***		***2008***	
	Off	***In***	***Off***	***In***	***Off***	***In***
Daily issues	**17.2**	**17.2**	**19.5**	**22.4**	**16.2**	**28.9**
Friends	6.7	5.9	4.6	10.2	4.3	5.6
Sport	2.2	1.9	2.8	2.0	2.5	2.1
Active leisure	0.6	0.4	2.8	0	1.4	1.8
Cinema	0.2	0.4	0	2.0	0.8	1.2
Theatre	0.1	0.7	0	2.0	0.2	0.6
Restaurants	3.1	1.1	3.7	2.0	3.4	3.5
Oth.entertainment	0.9	2.6	0	2.0	3.4	3.8
Garden/forest	0.2	0	0	0	0.3	1.2
Leisure	**14**	**13**	**13.9**	**20.2**	**16.3**	**19.8**
Home	**36.2**	**38.3**	**32.4**	**34.7**	**32.9**	**28.9**

Those respondents also had indicated necessity for physical trips if they didn't have access to Internet (Table 3.22). One can see that ordering food and other goods replaces physical trips by 100 percent among in campus residents, while only 93.8% of respondents living outside campus would need physical trip if they wouldn't have access to Internet, that means that 6.2 of them ordered food because of other than lack of commercial infrastructure reasons.

Table 3.22. Comparison of virtual mobility by trips purpose (2006–2008)

Virtual trip	**Off campus**		**In campus**	
	Yes %	**No %**	**Yes %**	**No %**
Info	61.6	38.4	73.5	26.5
Goods	**91.8**	8.2	**97.8**	2.2
Food	**93.8**	6.2	**100**	0
Bills	85.2	14.8	86.8	13.2
Charting	40.2	**59.8**	34.1	**65.9**
Games	70.6	29.4	70	30
Movies	59.4	40.6	58.1	41.9
Music	59.2	40.8	48.2	51.8
E-mail	24.1	**75.9**	23.1	**76.9**
Phone	45.7	54.3	46.2	53.8
Texts	45.7	54.3	46.2	53.8

All the results presented made a high input for proving one of research questions – what factors are influencing one's physical and virtual mobility and formed clear principles for suggestions how such data should be integrated into land use and social infrastructure planning as well as for land use regulations near particular objects (see ch. 4).

3.4. Substitution of physical trips by virtual ones

In summary the above presented analysis with various attitudes to factors influencing respondents' mobility formulates some assumptions for further research (Jauneikaite, Carreno 2009):

- Part of virtual trips takes away the flow from the public transport, however, we need to find out those virtual trips that would help to reduce the number of trips by private car;
- Most likely, the virtual trips replace part of work-related trips, household (shopping) and leisure (visiting friends) trips;
- It is possible that respondents change short daily and leisure trips over to virtual alternatives and so they decrease the number of physical trips made per day, but the time "meant" for physical activity remains similar. That could be assumed as the fact that virtual trips are not decreasing

travelling demand, just change mobility itself in time and space (Jauneikaite 2007).

So the main task for the following subchapter is to confirm or to deny the listed assumptions.

3.4.1. Virtual activities and virtual trips

The main assumption of all the surveys done – the use of the Internet replaces a certain number of transport trips so far. First of all, to check this assumption previously obtained results (2006–2007) of virtual and physical mobility diaries were used (Jauneikaite 2007). To ensure a higher reliability of the survey the target group has been analyzed as a whole, without dividing it into sub-groups. The physical trips or time spent on the Internet, indicated by the respondents according to their goal, were divided into 4 groups:

a) info search on the Internet (the equivalent – work-related transport trips);
b) goods, services (the equivalent – household trips);
c) communication (the equivalent – meeting the friends, relatives);
d) entertainment (the equivalent - sport, movies, etc.).

Trying to make the survey more objective, initial data was assessed not in the quantitative but in percentage terms. Duration indicated by the respondents as spent on the Internet was re-calculated into times and attributed to the group according to the goal of use, thus, the obtained results could be compared to physical trips. Physical mobility is presented as a percentage of trips attributed to a certain travelling group (according to the goal) from the total number of the trips. The summarized results are given in Table 3.23.

Table 3.23. Percentage distribution of Internet use and transport trips according to the goal

Type of mobility	Goal			
Virtual mobility	Info search for the studies	Goods, services	Communication	Entertainment
	26%	5%	**47%**	**22%**
Physical mobility	Studies, work	Goods, services	Communication	Entertainment
	54%	26%	**7%**	**13%**

The results of this survey, since data of at least several-year dynamics is not available so far, all by themselves are not very representative, though the tendency is already clear – time spent on the Internet is getting longer, whereas the trips made for communication and entertainment is amounting to hardly 20% of all the trips made by the target group. The largest attention should be paid to the fact that the target group is 20–24 year old studying people, having relatively less business-related or social responsibilities than other social groups, thus, they have more time for an active communication “tête-à-tête“.

Table 3.24. Time spent on the Internet according to the purpose of its use

2006							
Having Internet at home				Having no Internet at home			
Info search	Goods, services	Communication	Entertainment	Info search	Goods, services	Communication	Info search
24 min	2 min	53 min	41 min	19 min	1 min	14 min	6 min
2007							
Info search	Goods, services	Communicat.	Info search	Info search	Goods, services	Communicat.	Info search
18 min	1 min	53 min	55 min	39 min	0 min	12 min	3 min

Unfortunately, based on the results of this survey, those are people who spend nearly 3 hours per day (Table 3.24) for communication and entertainment (by watching movies, playing video games, etc), while their real trips, e. g. to the cinema or to the theatre, make less than 1% of all daily transport trips and this once again confirms the assumption made at the beginning of the survey about the changeability of trips with the Internet services.

Unlike usual practice (The Virtual Mobility Knowledge Base lists four categories of virtual mobility) the authoress, taking into consideration the specific features of the target group, in the survey divided the types of virtual trips into 10 classes:

- search for information for studies/work;
- ordering manufactured goods;
- ordering food for home delivery;
- payment of bills;
- e-correspondence – *n* received mail, *n* sent mail (the number *n* was indicated by respondents);
- mobile phone usage – *n* made calls, *n* received calls, *n* sent SMS, *n* received SMS (the number *n* was indicated by respondents);
- socialization on public (readily accessible portals) or private (MSN, ICQ, Skype, etc.) chartrooms;
- playing games;
- downloading movies;
- downloading music;
- other (were indicated by respondents).

Such a diary structure was chosen in order to separate as precisely as possible those virtual activities which have no large influence on physical mobility compared to the real virtual trips. In order to formulate more comprehensive conclusions and following the principle of "*communication diaries*" in 2008 our previous diary was supplemented with the question „If You have no access to telecommunications would You do a physical trip?" and with a possibility to point out which transport mode was avoided by the respondent, what would be the distance of the trip and how long would it take to make it. Below are the results of physical trips substitution by virtual trips according to trip purpose.

Search for information

From the total sample who reported making a 'virtual trip', 223 reported making a virtual trip for information search purposes (Table 3.25). Those trips are mainly substituting PT (61%), distance would amount to approximately 13.8 km.

Table 3.25. Replacement of physical work and studies related trips

Mode replaced		%	Time, min	Distance, km
Car	**Driver**	16	33	13.3
	Passenger	2	19	7.3
PT	**Trolleybus**	38	48	13.3
	Urban bus	23	70	14.3
	Taxi			
Walk/cycle		21	19	3.9

% = percentage of total sample using each mode

Ordering of manufactured goods

From the total sample who reported making a 'virtual trip', 147 reported making a virtual trip for ordering of goods (Table 3.26). Those trips are mainly substituting walking and cycling (39%), the distance covered would be done approximately 1.6 km.

Table 3.26. Replacement of physical shopping trips

Mode replaced		%	Time, min	Distance, km
CAR	**Driver**	22	24	14.1
	Passenger	5	5	9.3
PT	**Trolleybus**	24	23.3	7.9
	Urban bus	10	60	11.5
	Taxi			
Walk/cycle		39	37	1.6

% = percentage of total sample using each mode

Ordering of food for home delivery

From the total sample who reported making a 'virtual trip', 117 reported making a virtual trip for ordering food (Table 3.27). Those trips are mainly substituting car and PT (36% each), distance would reach approximately 8.2 km.

Table 3.27. Replacement of physical food shopping (eating) trips

Mode replaced		%	Time, min	Distance, km
CAR	**Driver**	29	26	7.7
	Passenger	7	31	9.1
PT	**Trolleybus**	25	45	6.0
	Urban bus	11	36	9.9
	Taxi	-	-	-
Walk/cycle		27	19	2.2

% = percentage of total sample using each mode

Payment of bills

From the total sample who reported making a 'virtual trip', 152 reported making a virtual trip for paying their bills (Table 3.28). Those trips are mainly substituting PT (41%), distance would be as long as approximately 9.5 km.

Table 3.28. Replacement of physical trips for paying bills

Mode replaced		%	Time, min	Distance, km
CAR	**Driver**	28	35	10.2
	Passenger	4	33	7
PT	**Trolleybus**	30	36	7
	Urban bus	11	46	12
Walk/cycle		27	20	1.9

% = percentage of total sample using each mode

Socialization on public or private chartrooms

Table 3.29. Replacement of physical socializing trips

Mode replaced		%	Time, min	Distance, km
CAR	**Driver**	30	55	43.4
	Passenger	3	29	19.3
PT	**Trolleybus**	22	49	8.5
	Urban bus	31	55	16.7
	Taxi	2	14	16
Walk/cycle		12	20	2.7

% = percentage of total sample using each mode

From the total sample who reported making a ‘virtual trip’, 134 reported making a virtual trip for communicating via chartrooms (Table 3.29). Those trips are mainly substituting PT (53%), the distance would reach approximately 13.7 km.

Playing games

From the total sample who reported making a ‘virtual trip’, 117 reported making a virtual trip for playing games (Table 3.30). Those trips are mainly substituting PT (46%), distance covered would be approximately 12.7 km.

Table 3.30. Replacement of physical leisure trips

Mode replaced		**%**	**Time, min**	**Dis-tance, km**
CAR	**Driver**	30	33	18.3
	Passenger	10	23	15.9
PT	**Trolleybus**	26	46	11.4
	Urban bus	23	55	14.0
	Taxi	-	-	-
Walk/cycle		11	26	3.2

% = percentage of total sample using each mode

Downloading (watching online) movies

From the total sample who reported making a ‘virtual trip’, 82 reported making a virtual trip for watching movies (Table 3.31). Those trips are mainly substituting car (56%), the distance would be done approximately 18.3 km.

Table 3.31. Replacement of physical leisure trips 2

Mode replaced		**%**	**Time, min**	**Distance, km**
CAR	**Driver**	38	40	17.6
	Passenger	18	28	19.1
PT	**Trolleybus**	15	50	13.6
	Urban bus	25	42	9.5
	Taxi	1	2	5.0
Walk/cycle		3	20	3.0

Downloading (watching concerts online) music

From the total sample who reported making a ‘virtual trip’, 56 reported making a virtual trip for watching movies (Table 3.32). Those trips are mainly substituting PT (50%), the distance would be approximately 12.3 km.

Table 3.32. Replacement of physical leisure trips 3

Mode replaced		%	Time, min	Distance, km
CAR	**Driver**	30	24	17.4
	Passenger	13	28	14.6
PT	**Trolleybus**	21	56	14.2
	Urban bus	27	40	10.4
	Taxi	2	20	13
Walk/cycle		7	24	2.1

% = percentage of total sample using each mode

E-correspondence

From the total sample who reported making a 'virtual trip', 54 reported making a virtual trip for communicating via e-mail (Table 3.33). Those trips are mainly substituting PT (51%), the distance would be about 24.3 km.

Table 3.33. Replacement of socializing or work related trips

Mode replaced		%	Time, min	Distance, km
CAR	**Driver**	35	84	48.8
	Passenger	6	23	7.3
PT	**Trolleybus**	20	48	10.0
	Urban bus	31	58	38.5
Walk/cycle		8	18	2.3

Mobile phone (calling)

From the total sample who reported making a 'virtual trip', 145 reported making a virtual trip for communicating via mobile phone (Table 3.34). Those trips are mainly substituting PT (51%), distance would be done approximately 27.1 km.

Table 3.34. Replacement of socializing or work related trips 2

Mode replaced		%	Time, min	Distance, km
CAR	**Driver**	33	129	104.4
	Passenger	7	129	139.3
PT	**Trolleybus**	22	52	12.7
	Urban bus	27	82	54.4
	Taxi	2	21.3	14.3
Walk/cycle		9	14	1.8

% = percentage of total sample using each mode

Mobile phone (texts)

From the total sample who reported making a 'virtual trip', 146 reported making a virtual trip for communicating via sms (Table 3.35). Those trips are mainly substituting PT (51%), the distance would be about approximately 31.1 km.

Table 3.35. Replacement of socializing or work related trips 3

Mode replaced		%	Time, min	Distance, km
CAR	**Driver**	32	138	97.5
	Passenger	7	129	150.4
PT	**Trolleybus**	22	50	13
	Urban bus	29	78	49.3
	Taxi	-	-	-
Walk/cycle		10	26	2.4

% = percentage of total sample using each mode

3.4.2. The final results from physical trips' substitution by virtual ones

According to physical trips, identified in the mobility diaries, the modal distribution of trips was defined by their purpose and transport mode in each of research years (see Table 3.36 and 3.37).

Table 3.36 gives the systemized results of the diaries of physical trips where PT (public transport) shows all the trips made by trolleybus, bus, mini-bus, private bus, train; the "Car" column shows the trips made by office car, by car as a driver and as a passenger, Friendly transport – trips made by bicycle or on foot. Due to insufficient sample of survey results the Table gives no results of 2007, though they also confirm an obvious tendency of the decrease in the use of public transport and increase in the use of private cars.

Table 3.36. Comparison of students and adults trips by mode

Mode	Physical trips (2006)	Physical trips (2008)	Virtual trips (2008)
PT	53.5	44.8	48.0
Car	32.6	41.2	34.2
Friendly trip	13.8	13.9	17.8

Table 3.37 gives the structure of trips made by the respondents per day (2006 and 2008, also the results of adults survey).

Table 3.37. Comparison of students and adults trips by purpose

Purpose	Students in 2006	Students in 2008	Virtual trips 2008
Studies and work related	32.4	32.1	41.4 (labels "search for info", e-correspondence and usage of mobile phone are summed up) 28 (be home)
Shopping	**12.5**	**10.4**	19.3 (labels "ordering food", "ordering manufactured goods" are summed up – 13.1
Other daily trips (kindergarten, health related, etc.)	4.7	8.2	11.1 (payment of bills) – 7.5
Leisure trips (all):	7.3	12.5	18.6 (labels "playing games", "downloading movies or music" are summed up – 12.6
Friends	**6.6**	**4.8**	9.8 (socializing) – 6.7
Home	**36.5**	**32.0**	– (32)

It is evident that the number of trips that can be replaced with virtual trips has been slightly decreasing, i.e. during two years (data of 2007 is not included) the percentage of work-related trips as well as shopping trips had decreased by 0.5 and 2.1 percent respectively from the total structure, almost by 6 percent from the number of work-related trips and almost by 17 percent from the number of trips made for shopping purposes. This allows to make an assumption that the number of these trips has decreased after they were replaced with virtual trips, e. g. instead of office meeting an electronic or mobile correspondence was used, instead of the trip to several shops – Internet shopping was made and so on.

Table 3.38. Comparison of students and adults leisure trips by purpose

Purpose	Students in 2006	Students in 2007	Students in 2008	Adults in 2008
Friends	6.6	6.0	4.8	1.1
Sport	2.0	2.4	2.4	0
Active leisure	0.5	1.8	1.5	2.8
Cinema	0.3	0.6	0.9	0
Theatre	0.3	0.6	0.3	0
Restaurants	2.8	3.0	3.4	4.6
Ot. entertainment	1.2	0.6	3.5	0
Garden/forest	0.2	0	0.5	0.7
Leisure	**13.9**	**15**	**17.3**	**9.2**

Having in mind a specific and young target group the separate survey was conducted on the distribution of leisure-time trips in a day time (see Table 3.38). One can see that with the decrease in the total number of leisure trips the number of trips to meet friends during the two research years had decreased by 1.8 percent from the total structure or by more than 27 percent from the number of trips to meet friends (relatives).

Comparison of those two tables above and results presented in ch. 3.4.1 shows such tendencies in physical and virtual mobility:

- Percentage of trips made by car was increasing (in 2008 there were 26% more trips by car than in 2006) during the last years and thus part of the trips made by public transport was decreasing (in 2008 there were 16% less trips by PT than in 2006). And the overall mobility was decreased (from 3.72 trips on the average for person per day in 2006 to 3.18 in 2008);
- Decrease in physical shopping trips by 16.8% in 2008 compared with the year 2006 might be explained by 19.3% of all virtual trips made by the same respondents. Every second survey participant has made such a trip.
- Decrease in trips related to studies and work is not as obvious (changed by less than 1% in 2008 compared with 2006), but it also can be explained by high percentage of virtual trips saved by not going to the library, not meeting interested persons personally.
- Following the purpose of the trip, the most frequently done are work and studies related trips (41.4% from the whole sample), shopping trips (19.3%) and daily (e. g. paying bills) trips (11.1%).
- Virtual trips mostly substituting physical trips would be made by car – leisure trips (47% of virtual trips made would be by car), virtual tips "saving" the longest distances (average – 52 km) are socializing or work-studies related virtual trips via E-mail and Mobile phone (short text messages as well).
- Not all virtual trips are important for urban planning and transport engineering – those results show that 71.8% of them are replacing physical trips (all virtual trips excluding leisure and socializing trips). The biggest influence on land use and urban engineering is made because of shopping and other daily virtual trips (30.4% of all virtual trips).

3.5. Model of physical trips' substitution by virtual trips

The main purpose of mobility management is to decrease the number of trips by car and to encourage usage of friendly transport (public and non-motorized). Having in mind this objective and after summarizing results of chapter 3, the model of physical trips substitution by virtual ones is presented (Fig. 3.10). This model illustrates in what circumstances, under what conditions and what type of physical trips can by substituted by virtual ones.

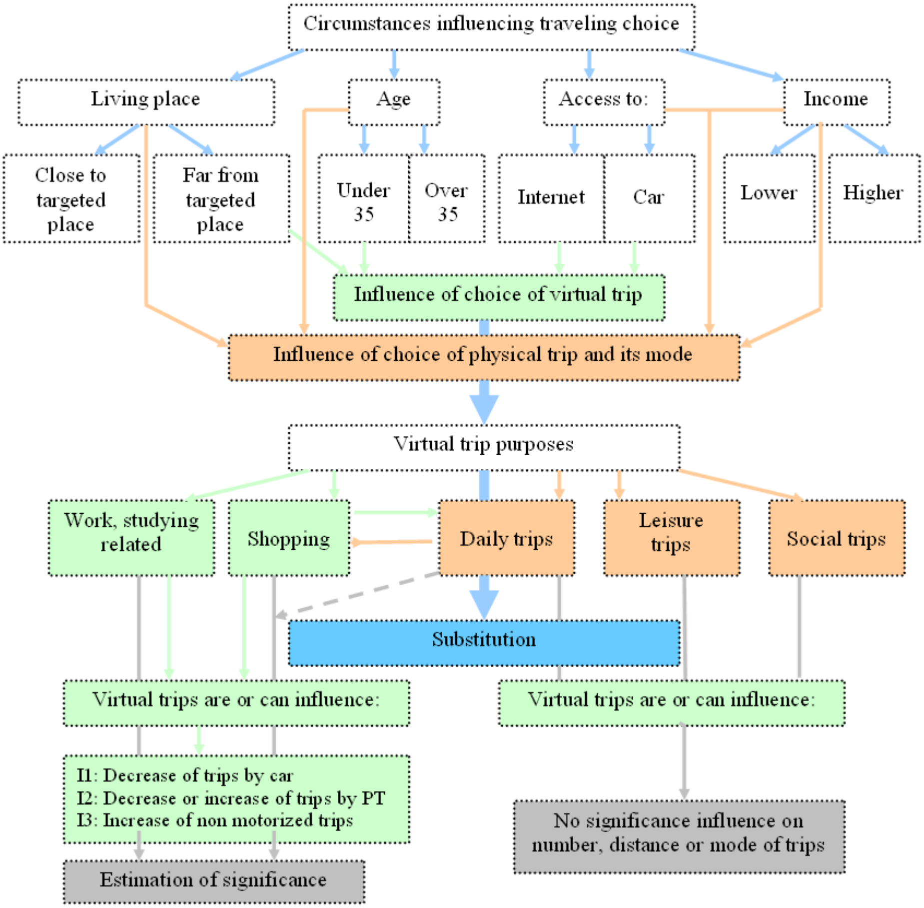


Fig. 3.10. The model of physical trips substitution by virtual ones

Here we can see that the access to the Internet and the car has a slight dependence on income and both together they make influence on physical mobility, as well as the living place and age. The virtual mobility depends mostly on citizens' age (the younger person, the higher level of virtual mobility), access to the Internet and no access to car usage are slightly modifying virtual mobility too.

Analyzing trips by its purpose we can see that most likely replaced by virtual trips will be 5 types of trips, out of which only two types of virtual trips are likely to make influence on overall physical mobility and thus are important as the further research topic for urban engineering. After all research and analysis made so far the author states, that most significantly and positively influencing urban engineering and mobility is e-shopping, which can decrease car usage and save progressively land and construction costs.

The second group of the most important trips is work and studying related virtual trips. So the aim raised up for chapter 4 is to discuss results obtained and to find the possibility to use them in land use planning, urban engineering and transport infrastructure planning.

3.6. Conclusions of the third chapter

1. It was estimated that the main predictors for respondents' mobility and behaviour in choosing a number of physical trips, its mode or virtual mobility as an alternative are the year of research (χ^2 (1, N = 690) = 8.84, $p > 0.05$), weekday (χ^2 (1, N = 899) = 27.58, $p > 0.001$), (χ^2 (1, N = 654) = 203.86, $p > 0.001$) and age (χ^2 (1, N = 815) = 10.36, $p > 0.001$), (χ^2 (1, N = 529) = 6.1, $p > 0.05$).

2. Evidently, with regard to physical as well as virtual trips the respondents are mostly mobile in the middle of the week and the least mobile in the beginning of the week and on Sunday. This suggests one more assumption – a part of physical as well as virtual trips (according to their purpose – household, work-related trips) are unchangeable and must be made irrespective of theoretically influencing outside factors (e. g. if the employer disagree with your working at home – you must make at least two work-related trips per day).

3. Though living place wasn't estimated as important factor in overall research sample, significant differences among both groups mobility were obvious. Living off campus residents are significantly more physically active (χ^2(1, N = 875) = 7.15, $p < 0.01$) and make more trips per day (χ^2(1, N = 817) = 12.77, $p < 0.01$). Those who are living in campus are connected to the Internet at higher rate and make on the average 0.4 more virtual trips per day. This suggests that within the target group' living area there are insufficient social infrastructure as well as transport infrastructure (cycling paths, PT accessibility) is not as sufficient as it is necessary.

4. Following the purpose of the virtual trips, the most frequently made are work and studies related trips (41.4% from the whole sample), shopping trips (19.3%) and daily (e. g. paying bills) trips (11.1%). Virtual trips substituting mostly physical trips would be made by car – leisure trips (47% of virtual trips made would be performed by car). Virtual trips "saving" longest distances (the average – 52 km) are socializing or work-studies related virtual trips via E-mail and Mobile phone (short text messages as well). But not all virtual trips are im-

portant for urban planning and transport engineering – those results show that 71.8% of them are replacing physical trips (all virtual trips excluding leisure and socializing trips). The biggest influence on land use and urban engineering is made because of shopping and other daily virtual trips (30.4% of all virtual trips).

5. Having in mind the main purpose of mobility management (to decrease number of trips by car and to encourage usage of friendly transport), after summarizing of all results obtained - the model of physical trips substitution by virtual ones was created. This model illustrates in what circumstances, what conditions and what physical trips can by substituted by virtual ones and helps to form clear principles for suggestions how such data should be integrated into land use and social infrastructure planning as well as for land use regulations near particular objects.

4

Integration of virtual mobility data into planning process and building regulation

One of the tasks set for this research was to estimate possibilities to adopt and integrate model of virtual mobility in urban engineering and transport infrastructure planning. Therefore the aim of this subchapter is to make a brief overview of the most important factors for urban planning, main principles and methodology being used till now, its advantages and limitations. Virtual and physical mobility research was carried out to define a possibility of physical trips (their purpose, length, transport mode) to be replaced with virtual trips, and to identify the influence of this replacement on the planning of territories and transport infrastructure. Based on the obtained results the main assumptions have been formulated allowing to more effectively plan the land-tenure of transport and social infrastructure and to optimize new construction.

Based on results of this chapter 4 articles were published (Juskevicius, Jauneikaite 2008; Juskevicius *et al.* 2008; Juskevicius *et al.* 2008; Jauneikaite, Carreno 2009).

4.1. Mobility management integration into urban planning

The table given above (4.1) illustrates the main land use and urban planning and planning promoters. Here (Fiedler 2007) the summary of planning practice in various European countries is presented.

Table 4.1. Analysis of planning practices in Europe (Fiedler 2007)

planning promoters	**land use planning** (strategic planning promoted by the public authority, based on typical functions, without promoter involvement, long-term)	**urban planning** (conducted by the public authority, often driven by developers, involving several functions and promoters, typical, medium-term)
national or regional authorities	**A1** - regional development plans, sectorial plans (e.g. water, transport)	**B1**
municipal authorities	**A2** - urban development plans, zoning, sectorial development (e.g. green spaces)	**B2** - industrial parks, social housing estates, requalification of harbour areas, brownfields, commercialization of public land
public service corporations (housing associations, transport and energy corporations, public universities, medical institutions, municipal or state real estate holdings)	**A3**	**B3** - as above, plus: subsidized housing, universities, hospitals, commercial areas around stations
private corporations	**A4**	**B4** - shopping centres, entertainment parks, business parks, free-market and leisure housing (such as golf resorts, gated communities)
individuals or small enterprises	**A5**	**B5**

There are even more planning levels in Lithuania than in some other European countries, but they don't really state the need for such integration. All earlier prepared regulative planning documents note need for transport impact assessment, declare necessity to plan everything with attitude to sustainable development but so far all land use planning documents stop short at planning new parking sites, wider streets and the best that can happen in these documents – plans for new cycling paths and indication of necessary public transport routes, stops and etc. Lithuanian land use planning documents are presented in four levels (national, regional, district and local) and three main types (comprehensive, special and local). Attitude to mobility management can appear in all levels and all types of land use planning but more often by initiative of local (municipal) representatives it finds place in some kinds of strategic planning documents (feasibility studies, investment projects, new development validation) but it does not really appears in reality (the situation has been analyzed in depth and results presented in ch. 1.5). However mechanism for legal mobility management integration and thus virtual mobility data usage into the land use planning process exists

For proper integrating virtual and physical mobility management into the planning process awareness of both planners and organizers and new legal recommendations are needed and they are obligatory (see ch. 4.1.2, 4.2 and 4.3). But first of all, for the proper indication of the problem and possible monitoring of mobility management results a constant collection of data is necessary (see ch. 4.1.1).

4.1.1. Proposals for collection and monitoring of the data on mobility indicators

In the opinion of the authoress, in Lithuania it is advisable to arrange a continuous monitoring of population mobility indicators in the database. Hereby the author suggests for mobility monitoring to use practice from the particular virtual and physical mobility research and data collecting process.

Table 4.2. Description of all travels per one day

Please indicate the time taken for the first, second, third, etc. travel (in minutes).

Transport mode	Day travels													
	1		2		3		4		5		6		7	
	T	K	T	K	T	K	T	K	T	K	T	K	T	K
Did not travel														
Trolleybus														
Urban bus														
Office bus or car														
Car, as a driver														
Car, as a passenger														
Mini-bus														
Private bus														
Taxi														
Bicycle														
Train														
On foot														

Note: T – travel duration, min; K – travel purpose (see the list below) and walking to the public transport stop should be included into the time of travel by the public transport

The practice showed that such structure of mobility diary (Table 4.2) allows collecting all necessary data about physical trips – number of trips, mode, travelling duration (T) and travel purpose (K). The codes for travel purposes are and have to be provided in a separate, easy to use list. There is also very important to note to the respondent in what dimension (meters, minutes and etc.) characteristics of the trips should be described.

Sometimes for planners it is very essential to have information not only about number and mode of trips done, but also about time about trips start time. In such case the Table 4.2 can be improved (see Table 4.3) with one additional column for start time indicating, where e. g. value S1 would mean that trip was started at 0.00–1.00 a.m., S5 would mean trip start at 4.00–5.00 a.m. and so.

Table 4.3. Columns for trips start time indicating

1			2–9			10		
S	T	K	**S**	T	K	**S**	T	K

For collecting data about **virtual activities** it is enough to provide simple questions as it is presented in Table 4.4.

Table 4.4. Columns for trips start time indicating

Please indicate the reasons, goals and tasks carried out on Internet yesterday, also please indicate time (in minutes) taken for that:

Internet services	Time taken
Search for information for studies/work	
Ordering of manufactured goods	
Ordering food for home delivery	
Payment of bills	
E-correspondence *…received mail, …sent mail (indicate the number)*	
Socialisation on public (readily accessible portals) or private (MSN, ICQ, Skype, etc.) chartrooms	
Playing games	
Downloading movies, music	
Other (indicate)	

But for getting direct information about **virtual trips made** this table has to be supplemented with additional questions, whether physical trip was replaced, that mode hadn't been used, what time and distance was saved (see more in ch. 2.3.2).

When such data is collected, database for monitoring can be done following the author's practice and recommendations described in ch. 2.3.5 or in any other relative way, though method of data coding was really purposeful if to have in mind the proposed statistical techniques for data processing.

It is essentially important to have national support for data collection and monitoring. Potential organizers of national level surveys should be the Department of Statistics and/or the Ministry of Transport and Communications. But different data organizers (government, municipalities, planners and etc.) can collect and monitor different data (quantity, reliability, specific, level) on their own, but if that were done in the same way, following same recommendations, data collected by different organizers later on can be assembled into one interactive data source available for all potential data users – scientists and practitioners.

If such data monitoring system is established, it will be possible to relate information observed to the needs of population for physical mobility, transport and social infrastructure as well as forecasting of such means for meeting the citizens' needs.

4.1.2. The possibilities to adopt virtual mobility data in planning process

In the author's opinion, virtual mobility data is important and could be adopted at least in three types of strategic and land use plans:

- Transport infrastructure plans;
- Social infrastructure plans;
- Parking regulation through BTR.

All above listed planning issues can be solved in different level and type plans, using data of physical trips substitution by virtual ones as background for decisions or as MM measures.

Plans for ***transport infrastructure*** can be also divided at least in two groups:

- Market demands and its claims with respect to mobility are known (solution for status quo situation);
- Plan's solutions which are meant for unknown user (solutions for target groups and their needs which are not yet clear).

The solving of the transport problems in Western Europe, already 40 years ago had began with restriction of car traffic in the downtowns of cities. Today it is core for cities communication policy: first of all it means priority for pedestrians and cyclists and PT; secondly, restriction and management of car usage by all possible means, starting with forming urban structures and ending with technical and political measures (Juskevicius *et al.* 2008).

There is a large group of European countries where in policy statements, especially at national level, the benefits for sustainable transport of policies such as increased development densities, high densities at transport nodes, and development along transport axes, are all recognised and encouraged. These include Slovenia, Sweden, the Netherlands, to an extent Germany and, increasingly, Spain. Here, in theory, these policies should make their way from national and state level statements into local plans, but often are not due to local political pressures. Another reason why they may not be put into practice is because transport policy is not itself orientated towards sustainable transport objectives, as in Slovenia, for example. Then there is a final group where these policies seem to be put into practice, at least to some extent. These include Switzerland, the UK and (to a much lesser degree) Ireland.

This begs the question of why this situation has come about in these countries. In the UK, this is due to a strong political steer from central government on this policy from the mid 1990s onwards, due to concerns about urban sprawl and traffic congestion, especially in southeast England. The UK system has, since 1947 at least, had a high degree of central influence over local planning policy and decisions, so this national policy has made its way into local policy and practice. Ireland's planning system derives from that of the UK and there is considerable interchange of transport and planning professionals. Since economic growth in Ireland has led to massive traffic congestion in larger towns and cities, there has been some consideration of UK methods to deal with this. In Switzerland, these policies are enacted due to a long tradition of environmental protection and promotion of alternative modes of transport, especially public transport.

In the three countries mentioned in the above paragraph, there is emphasis within the making of regional and local plans on orienting development around the existing or planned transport system, and especially the public transport system; and on using the plans to reduce the need to travel, especially by car. This means that development that generates a lot of trips, such as offices and shops, should supposedly be located where it can be served by public transport, and the land-use plans should indicate this. In this way, development of these types of land uses should be encouraged to locate in areas where its users can take public transport or slow modes. The degree to which this works varies due to local political pressures, but in making local land use plans in the UK and Switzerland, municipalities have a legal duty to show how they have taken into account higher level regional plans and national guidance. This helps to ensure some level of consistency between the planning levels, and that the developments that will generate the highest number of trips are often (although by no means always) located in areas that are better served by public transport (EU FP6 MAX 2008).

As it was said above, the right to be organizer of planning documents in Lithuania has:

- The Republic of Lithuania (LR), represented by different ministries and departments. At this level only national level documents can be prepared. It might be: national strategies, comprehensive plan (CP) which covers whole republic, national special plans (SP). National strategies and LR CP has to be approved by the government;
- The Counties. At this level regional documents are used to be prepared, like a strategic plan for a county, CP for this county, some other plans. These plans must be checked in responsible ministries and other institutions, before approving them by the county administration.
- Municipalities prepare documents at district level, it might cover all or a part of municipality area. All kinds of documents can be prepared at this level; municipality administration is the institution which officially takes role of Organizer in planning process. Documents can be such as follows: strategic plan for district development (rarely strategic plan for concrete issue, like for transport, economic etc.) various feasibility studies for complementing strategic plan, CP might be prepared for a whole district or cover just the chosen town and it's suburbs), SP might be prepared for the whole district (like special forestry plan, SP for layout of gas-stations) or some part of it (SP for big shopping centres and multi-storeyed buildings' position in some town). Detailed plans, initiated by municipality mostly are being prepared for some new areas built-up for residential purposes or redeveloping old areas. Detailed plans initiated by the developers are meant first of all for the purpose of the land use changing from one to another (e. g. from forest to commercial) and secondly for detailing situation on site, where street or building must be built.

National policy does states that it is very important to provide sustainable transport in the area of the whole country. It states that it is very important to use all possible means of transport including rail, air and water transport, which should increase needs for people and goods travelling by car. Government (Economy Ministry) organizes national special plans for bicycle routes, for water routes, auto tourism and so. Unfortunately these plans are meant more for promoting tourism, with less attention to daily needs of inhabitants. Better situation is in district level plans, comprehensive plans for districts and towns, where one of the most important parts is – communications system. Besides, there exist such documents as feasibility studies for transport system in particular towns. Unfortunately, they don't have any status and even if in this study transport system is planned very well it might just lay down in the municipality archive.

Planning system in Lithuania at the moment is in the state of renaissance. After the planned economy system collapsed in 90's, there were a lot of mistakes made in land reform and there were no other planning documents, just detailed plans with no regard to main urban structure of towns or perspectives of district.

Even if cities and towns had general plans, no monitoring was done to emphasize if and how it works, what benefits were achieved, what solutions were realized. But now as new initiatives are taken by the Government and the Environment Ministry to make territorial planning more effective and meeting the needs of the future, the chance for mobility and especially virtual mobility management integration into planning process is fairly reliable.

From the point of view of virtual mobility as an indicator of citizens needs, information about virtual trips can be used in three directions (Jauneikaite, Carreno 2009):

- Information about virtual trips replacing public transport trips **should be used for planning public transport routes** with attitudes to main target points which are avoided and replaced with virtual trips possibly because of insufficient PT supply.
- Information about virtual trips replacing non-motorized transport trips **should be used for planning non-motorized transport infrastructure** (optimization of bicycles and pedestrians paths, parking of bicycles).
- Information about virtual trips replacing car trips **should be used for parking regulation** with attitude to target points being avoided mostly (shopping centres, public institutions and recreational objects).

One of the main criteria for social infrastructure (commercial, leisure and other public institution) to be well served by car is a sufficient number of parking spaces. At the same time **parking spaces regulation** is one of the most effective mobility management measures.

The literature shows that there are a number of recognised ways that it is believed that such an objective can be brought about. One of the key amongst these is parking standards that limit the amount of off-street parking required to be provided with new developments in order to new parking to restrain car use to and from new developments.

Parking standards in most European Union states are set locally and as minimums, but can be limited in certain circumstances. In Switzerland and the UK they are set as national maxima (in the UK, only for larger developments); in both these countries it is typical to reduce these maxima in areas of higher public transport accessibility. In both the UK and Switzerland, national maximum parking standards are not legally binding, but there are strong reasons for municipalities **not** to ignore them. In Germany there are many examples of developers paying money to the municipality instead of providing parking on site; this money is then used to fund park and ride or public transport infrastructure (but not services). In addition, some municipalities in Germany, Sweden and the Netherlands do use reduced parking standards as a MM measure, but this varies by locality. Most countries have parking standards set either locally or in national building codes, but the idea of using parking restraint as a way of managing travel to and from a development is not common – this is only seen in Switzerland, the UK, Ireland, some cities and developments in Sweden and in certain German cities (e. g. Munich).

In the UK, in Scotland, prior to the introduction of national maximum parking standards in 2003, the Scottish Government commissioned work to assess the impact on inward investment of such parking standards, and concluded that the impact at a national level would be minimal. The redevelopment and re-use of brown field land and the return of people to city centres in the UK, Switzerland, Ireland and the Netherlands, amongst other places, shows that developers do not reject outright such policies but have been able to work within them and to continue to profit.

In Switzerland applicants for developments with more than 300 parking spaces planned have to deliver an environmental impact assessment study. These are evaluated by the cantonal authorities and if the environmental impacts are considered as too high it can lead to a reduction in the number of parking spaces sought by the applicant. The environmental impact assessment study is a part of the building permit process. In many countries, such as Spain, the Netherlands, rural Ireland and Poland, the municipality will normally have to satisfy itself that at least the stipulated minimum amount of parking is being provided by the developer (EU FP6 MAX 2008).

For objective estimation of real effectiveness of particular (by their purpose) trips on parking regulation within city, the real number of physical trips made by car and virtual trips which would be substituted by car were summed. Proportion among these trips was taken as basis for suggestion to change parking standards nearby the concrete public buildings. The results are presented in chapter 4.2 together with virtual mobility integration into urban engineering.

Social infrastructure in the terms of this research can be divided into two categories:

- The daily needs’ infrastructure (schools, kindergartens, shops);
- The infrastructure for periodic demands (libraries, medical institutions, entertainment enterprises).

Knowing how often particular infrastructure is needed is very important for mobility management and on the contrary – knowing where mobility is very high creates preconditions for social infrastructure demand. In order to get this knowledge very great attitude was paid to the analysis of virtual trips differentiated by their purpose (see ch. 3). The suggestions based on these findings are provided in ch. 4.2 and 4.3.

4.2. Recommendations for common virtual mobility impact and its data integration into urban engineering

Recommendations (A, B, C, D and E) for virtual mobility data integration into particular plans (transport, social infrastructure and land use for parking provision) are presented in certain subchapters below.

Based on the practice of foreign and Lithuanian scientists and engineers, the author named main mobility management integration into urban planning principles and adopted them into different according their purpose recommendations. Those also follows different sustainable development principles.

Recommendation A realizes a policy of **poly-centric urban structure and maximum parking standards;**

Recommendation B realizes a policy of **medium and high land-use densities with a mix of different uses;**

Recommendation C realizes a policy of **concentrating trip generating development along PT corridors;**

Recommendation D realizes a policy of **transport impact assessment;**

Recommendation E realizes a policy of **re-use of brown field sites.**

In terms of sustainability each of recommendation' embodies particular sustainable development principles: ensuring life quality (A), decreasing car usage (B), increasing PT (C) and non-motorised transport (D). Recommendation E is encouraging economical and material resources saving.

Below the common recommendations for purposeful virtual mobility data integration into land use and urban engineering planning are described in details.

4.2.1. Recommendation for virtual mobility data integration into urban planning according to trip purpose

A. This recommendation is meant for ensuring life quality, which means to integrate virtual mobility data into urban engineering process taking into account the most frequent virtual trips according to their purpose. **The most frequent by their purpose are virtual trips related with studies or work and daily trips** (see ch.3). In order to implement this recommendation and its tasks successfully, first of all, with the help of legal, normative and methodological acts poly-centric urban structure has to be encouraged. In such case there will be preconditions for every urban form (housing community, block, residential district) to function qualitatively and with some limitations to provide for residents possibility to use objects of elementary, advanced or even specific services. The implementation of such preconditions must be solved in cities and towns local plans, preparing conceptions of new urban developments and in detail development layouts. But first of all appropriate changes in legal planning and designing documents have to be settled up.

The principal scheme of recommendation A implementation sequence is given in Fig. 4.1. Corresponding suggestions for parking regulations are given below in this chapter and summarized parking requirements as well as overall suggestions for social infrastructure planning are presented in ch. 4.3.

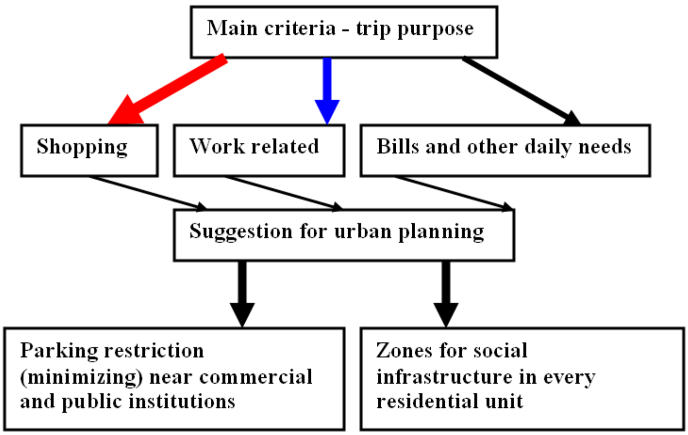


Fig. 4.1. Recommendation A – principal scheme

In terms of importance to the substitution of physical trips and thus positive impact on urban development – the most significant are shopping and other daily trips as decreasing them we can directly decrease the need of parking spaces near commercial objects.

According to the data obtained (see ch.3), physical and virtual trips by car with shopping purpose goes together as following:

if the number of physical **shopping and other trips** by car = 1 (n = 117);

then absolute number of overall **shopping trips** “by car”= 1+1.29 (where 1.29 indicates the size of virtual trips in this group and n = 151).

Such number allows us to suggest reorganizing parking standards and to increase requirements for parking spaces twice. Though for objective research and decision a deeper observation must be done, the author suggests that we should have in mind that these results were reached with very specific target group, which is a very representative group in terms of virtual mobility, but not as representative in terms of shopping infrastructure users. But following available data (number of trips by its mode and purpose, tendencies in increasing the Internet usage and services provided, tendencies in changes of modal split and mobility as well as tendencies in rapidly decreasing number of daily trips – see ch.3) the author suggests to change the existing quota in BTR (Table 4.5):

Table 4.5. Suggestion for parking regulation near shopping, commercial and financial institutions

Where applied	Existing status	Existing quota	Suggested status	Suggested quotas
Near offices, administrative enterprises	Minimum	1 place / 25 m^2 of ser. area	Minimum Maximum*	1 pl./ 38 m^2 1 pl./ 25 m^2
Near shopping and commercial centres	Minimum	1 place / 30 m^2 of ser. area	Minimum Maximum*	1 pl./ 45 m^2 1 pl./ 30 m^2

* - in many European countries instead of minimum parking standards – maximum standards are applied.

** - minimum standards can be feasible only if effective online services are applied.

In Lithuanian planning practice (*already prepared CP and planning methods)* three main principles are used for planning social infrastructure: **daily** needs objects (these refer in a way to those which the author names elementary services) must be planned with R = 600 m from living places, objects for serving **periodic** needs (these refer in a way to those which the author names advanced services) must be laid out with R = 1200 m from living places and the last objects serving **episodic** needs (these refer in a way to those which the author names specific services) must be laid out with R = 30 km from living places. The author agrees that it might be suitable in small villages with a distinct urban centre and practice with going out to another urban structure for meeting their episodic needs. But this doesn't fit at all to cities with poly-centric policy, so here and in all other recommendations the author analyzes special needs of residents and prepares the suggestions for the layout of a particular social object in urban structures.

Respondents had indicated that they would need to make 1.6–2.2 km (to and back) long trip by foot if they need to reach their shopping points (for food and manufactured goods). The similar distance (1.7 km, (to and back)) is for reaching major financial institutions and (or) other places for paying bills or(and) other simple banking, insurance, taxes and other operations. That allows us to confirm already known truth that citizens normally make their trips on foot or by other non-motorized transport only in case if it takes no longer than 15 min and the distance is not much longer than 1 km. Based on these and the following findings, the scheme for social infrastructure zones planning is presented in ch. 4.3.

4.2.2. Recommendation for virtual mobility data integration into urban planning following info about car usage for trips

B. The aim of this recommendation is to implement some planning principles which would allow decreasing the number of trips made by car. In terms of urban planning and engineering it is possible to implement by initiating development with a medium and high land-use densities and a mix of different uses. The implementation of such preconditions must be solved in cities and towns local plans (indicating density and integrality of different functions per zone) in such case the demand for travelling by car would be naturally managed and hopefully decreased. And also there should be restriction for car usage and storing in city centres and polycentres (described in ch. 4.2.1.) foreseen in special communication infrastructure and city's transport plans

The most often replacing car usage - are virtual leisure trips. The principal scheme of recommendation B implementation sequence is given in Fig. 4.2.

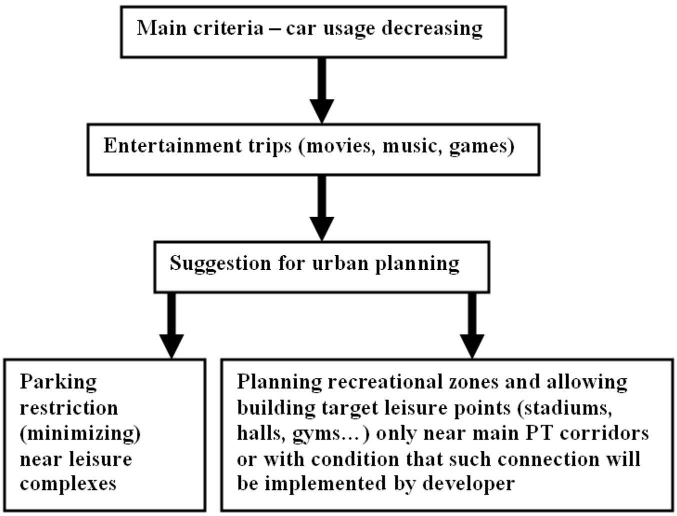


Fig. 4.2. Recommendation B – principal scheme

Following the data obtained (see ch.3), the most progressive suggestions would be:

- parking restriction near recreational objects;
- planning public spaces within living area and(or) easy to be reached by PT;
- building big leisure complexes only near by PT corridors;
- if such possibility (to build up public and leisure places near PT corridors) were not feasible, developers of such places would have to ensure a corre-

sponding development of PT (extended routes, new stops), this has to be foreseen in cities (towns) CP and building technical regulations.

According to the data obtained (see ch. 3), physical and virtual trips by car with recreational purposes go together as follows:

if the number of physical **leisure trips** by car = 1 (n = 117);

then absolute number of overall **leisure** trips "by car"= 1+1.38 (where 1.29 indicates the size of virtual trips in this group and n = 161).

Such a number allows us to reorganize parking standards and to increase requirements for parking spaces twice. Though for objective research and for a decision a deeper observation must be done, the author suggests having in minds that these results were reached with very specific target group, which is very representative group in terms of virtual mobility, but not so representative in terms of overall citizens using leisure and recreational complexes. But following available data (number of trips by its mode and purpose, tendencies in increasing Internet usage and services provided, car ownership increase, tendencies in changes of modal split and mobility as well as tendencies in rapidly decreasing number of daily trips – see ch. 3) the authoress suggests to change the existing a quota in BTR (which has to be applied while motorization level is 400 cars/ per 1000 residents, authoress estimated this condition and recalculated parking spaces needs accordingly to existing motorization level), see Table 4.6:

Table 4.6. Suggestion for parking regulation near recreational institutions

Where applied	Existing status	Existing quota	Suggested status	Suggested quotas
Near theatres, cinemas	Minimum	1 place / 6 places	Minimum** Maximum*	1 pl./ 10 pl. 1 pl./ 6 pl.
Near restaurants and coffee houses	Minimum	1 place / 15 m^2 of ser. area	Minimum** Maximum*	1 pl./ 24 m^2 1 pl./ 15 m^2

* – in many European countries instead of minimum parking standards – maximum standards are applied.

** – minimum standards can be feasible only if effective online services are applied.

The author also has analysed special residents' needs (as indicator their virtual trips were used) and prepared the suggestions for the layout of particular social objects in urban structures.

Respondents had indicated that they would need to make 2.1–3.2 km (to and back) by non-motorised transport to reach recreational points, public places, leisure centres or their alternatives. If they chose to go further by public transport, they would be able to do it within 8.5–16.7 km distance (to and back), but still they choose to do 161 virtual or 117 physical trips by car instead of alive entertainment. That was used as a basis for public and leisure places planning recommendations. Based on these and the following findings, the scheme for social infrastructure zones planning is presented in ch. 4.3.

4.2.3. Recommendation for virtual mobility data integration into urban planning following PT usage for trips

C. The aim of this recommendation is to implement some planning principles which would allow increasing the number of trips made by PT instead using car. **The most often PT is being replaced in socializing trips.** The principal scheme of recommendation' C implementation sequence is given in Fig. 4.3.

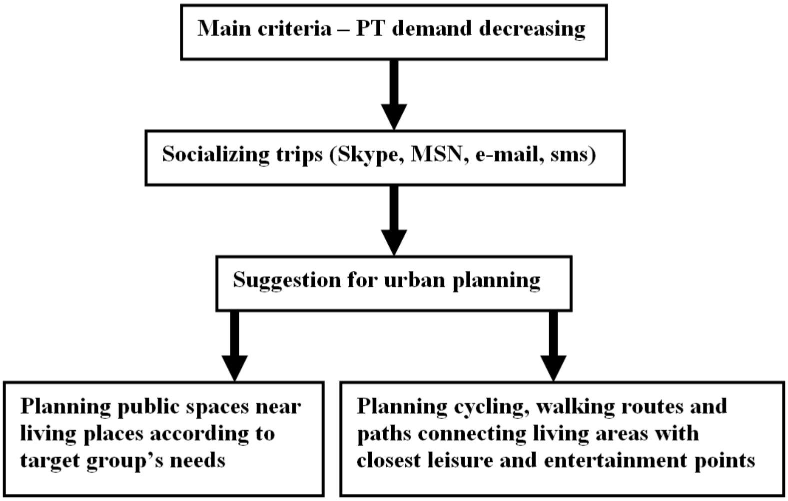


Fig. 4.3. Recommendation C – principal scheme

Following the data (see ch. 3), the most progressive suggestions would be:

- planning public spaces within living area and(or) easy to be reached by PT;
- planning walking, cycling routes, connecting living places with nearest recreational objects with length of 2–3 km.

Using results (ch. 3), which indicate what kind of trips are most likely to be replaced by virtual ones, the author prepared recommendations for PT accessibility (R = 600m) and public spaces location towards living zones (R = 1000 m) and PT corridors. Based on these and the following findings, the scheme for social infrastructure zones planning is presented in ch. 4.3.

4.2.4. Recommendation for virtual mobility data integration into urban planning following friendly transport usage for trips

D. The aim of this recommendation is to implement some planning principles which would allow increasing the number of trips made by friendly transport instead using car. The most often walking and cycling are replaced while performing daily trips (analysed more in model A). The principal scheme of recommendation D implementation sequence is given in Fig. 4.4.

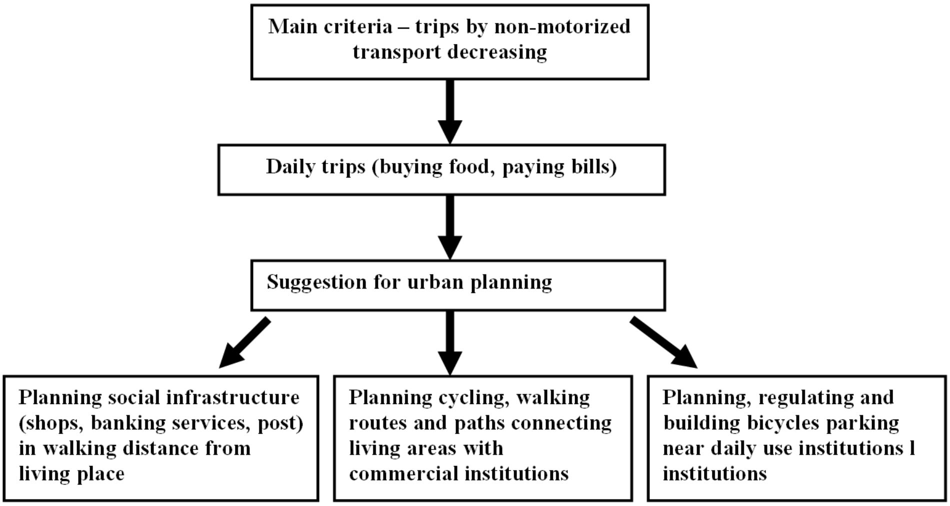


Fig. 4.4. Recommendation D – principal scheme

Following the data (see ch. 3), the most progressive suggestions would be:

- planning social infrastructure in walking distance (the scheme for social infrastructure is presented in ch. 4.3);
- planning cycling, walking routes which would connect living place with the most frequently used commercial and administrative target points (the scheme for walking, cycling routes planning is presented in ch. 4.3);
- planning and regulating bicycles parking near daily use institutions and housing.

Bicycles' parking is another important issue in Lithuanian planning system, as so far no regulation towards this question is provided in existing BTR or other related (*e. g. Law for non-motorized transport)* regulating documents. According to the data obtained (see ch.3), physical and virtual trips by bicycle with daily purposes go together as follows:

if the number of physical **daily trips** by bicycle = 1 (n = 8);

then absolute number of overall **daily** trips "by bicycle"= 1+2.88 (where 1.29 indicates the size of virtual trips in this group and n = 23);

if the number of physical **leisure trips** by bicycle = 1 (n = 7);

then absolute number of overall **leisure** trips "by bicycle"= 1+0.57 (where 0.57 indicates the size of virtual trips in this group and n = 4);

The sample of trips made by bicycle or possibly being replaced by virtual trips is very small if compared with the number of trips made by car. But still this allows making proportion (1/8.6 – daily trips, 1/25 – leisure trips) between car and bicycle parking, which is laid down below (Table 4.7):

Table 4.7. Suggestions for bicycle's parking regulation

Where applied	Existing quote	Existing quota for cars parking	Suggested quotas for bicycle parking
Near offices, administrative enterprises	Not applied	1 place / 25 m^2 of ser. area	Minimum 1 st. / 200 m^2
Near educational institutions	Not applied	1 place /6–40 pupils (depends from institution status)	Minimum 1 st. / every 50 children, pupil, student
Near shopping and commercial centres	Not applied	1 place / 30 m^2 of ser. area	1 pl./ 250 m^2
Near theatres, cinemas	Not applied	1 place / 6 vis. places	Minimum 1 st. / 150 vis. places and minimum 4 st./per building if there are less than 600vis. places
Near restaurants and coffee houses	Not applied	1 place / 15 m^2 of ser. area	Minimum 4 st./per restaurant or coffee house

4.2.5. Recommendation for virtual mobility data integration into urban planning following the longest distance for travelling to be saved

E. The aim of this recommendation is to implement some planning principles which would encourage economical and material resources saving. For embodying this aim in terms of urban engineering, the author suggests to initiate insistently (through cities and towns CP) reuse of brown fields which already have developed (often run out) transport and engineering infrastructure, thus not raising new demand for transport infrastructure. On the contrary existing infrastructure should meet the demand of potential brown fields users (usually it means unkept industrial areas near PT corridors.). **The longest travelling distance is being replaced by communicating (e-mail, mobile phone) trips.** That's why another measures to save economical and material resources are improving quality of existing housing, adoption of modern technologies in public and residential buildings and this can be realized through national investment program meant for buildings renovation. The principal scheme of model D implementation sequence is given in Fig. 4.5.

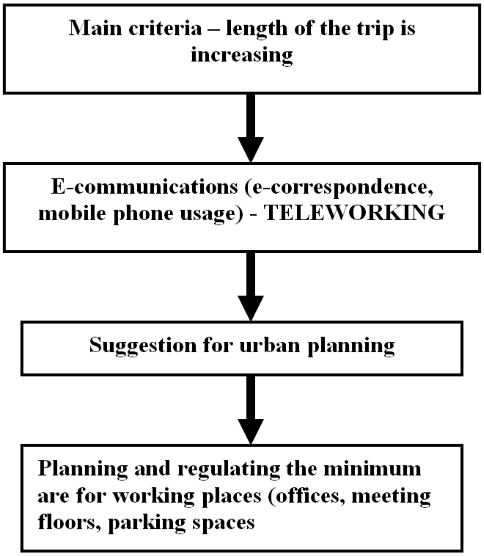


Fig. 4.5. Recommendation E – principal scheme

This recommendation is more meant to reach economical benefit of particular private or public body than to suggest something effective in terms of whole city urban planning. According to the valid *Lithuanian Hygiene Norms*, there should be minimum 6 m^2 and 20 m^3 per each person working with video terminal (personal computer). The practice shows, that normally offices, providing intellectual services (production of goods excluded) use approximately 7.5 m^2 per one working place and approximately 7.2% of the whole office area are used for meeting rooms, representative halls and similar non profitable spaces. This area could be saved only with prerogative of the administrator, by implementing teleworking, teleconferences system in office. This could keep at least the same regulation for minimum working place for employees and minimize the number of parking places according to the number of teleworking the enterprise has. The practice shows, that almost every office man could work at least one day per week at home, in that case the number of working places in e. g. company with 50 employees could be reduced to 45. The same principle could be adopted in regulating number of parking places for employees (as it was analysed parking regulation according to its visitors not employees in ch. 4.2.2).

4.3. Efficiency of virtual mobility in urban engineering

There are at least five different descriptions and dimensions of intelligent city (Komninos 2006, 2008) which strongly refer to the concept of sustainable city and its development. Thus both these concepts integrate three main dimensions for city to become intelligent and to be developed in sustainable way and these dimensions would be physical, institutional and digital spaces for city's population. This is why many scientists have been researching separately the impact of telecommunication usage to city's transport or to city's urban layout or to person social life quality improving (virtual mobility for disabled people, people with special needs, with limited economical resources and so) or all them together operating only *de facto* dimensions.

Whereas one of the main tasks for this particular research **was to find gaps how virtual mobility data could be used for forecasting and meeting citizens' social and daily needs in the particular urban structures.** So first of all theoretical model for virtual mobility research was created and this could be used as background for further researches in Lithuania and mobility data monitoring. Secondly authoress had designated that mechanism for legal mobility management integration and so virtual mobility data usage into land use planning process exists and virtual mobility data could be adopted in: transport infrastructure plans, social infrastructure plans, parking regulation through BTR. **This interpretation of citizens' virtual mobility data** (e. g. the fact that people are avoiding trips on foot longer than 800 m indicated the need for special infrastructure or the fact about lack of infrastructure) **is the main originality of work results and its value for civil engineering** (see results below).

General conclusions of the significance of virtual trips and virtual activities to people and to urban engineering – if the main criteria is time and the price of trips, people might save with virtual activities such as e-communication (in a way teleworking) and e-entertainment. From the land planner's attitude the main gap to be filled for better and more sustainable urban engineering is a special attitude to daily trips and possible advantage of teleshoping, e-governance, e-commerce and teleworking too. Summarizing he results of research and analysis made on the urban engineering, the author provides following:

- Recommendations for car parking regulation, to be implemented through changes in existing **BTR 2.06.01:1999, 1999 03 02. Nr. 61 (*with following changes*) Communication systems in cities, towns and villages.**

- Recommendations for bicycles' parking regulation, to be implemented through changes in existing **BTR 2.06.01:1999, 1999 03 02. Nr. 61 (*with following changes*) Communication systems in cities, towns and villages;**
- Recommendations for social infrastructure zones and walking, cycling routes planning in cities and areas with high density of population. At the moment **"Planning norms for cities, towns and villages (inhabited areas)"** are under preparation (initiator and organizator of this document - LR Environment Ministry). In the opinion of the author if the document is approved, the recommendations should be taken account in this document. Meanwhile some suggestions for planners can be given in **"The instruction for preparation of comprehensive plan for cities and towns" (approved by Environment Minister at 2004 05 07, order Nr. D1–263) and its *following changes*.**
- Recommendations for savings in land and constructional area optimizing the quotes for working places in offices, to be implemented through supplements in **"BTR 2.02.02:2004, 2004 02 27. Nr. D1-91 with following changes. Public buildings" and Lithuanian Hygiene Norms HN 32:2004, 2004 02 12, Nr.V-65 (*with following changes*). Working with Videoterminals. Requirements for Safety and Health.**

In Table 4.8 overall suggestions for parking restriction are presented (these were analysed in depth in ch. 4.2.1. and 4.2.2.

Table 4.8. Suggestions for car parking regulation

Where applied	Existing status	Existing quota	Suggested status	**Suggested quota**
Near offices, administrative enterprises	Minimum	1 place / 25 m^2 of ser. area	Minimum Maximum*	**1 pl./ 38 m^2** **1 pl./ 25 m^2**
Near shopping and commercial centres	Minimum	1 place / 30 m^2 of ser. area	Minimum Maximum*	**1 pl./ 45 m^2** **1 pl./ 30 m^2**
Near theatres, cinemas	Minimum	1 place / 6 places	Minimum** Maximum*	**1 pl./ 10 pl.** **1 pl./ 6 pl.**
Near restaurants and coffee houses	Minimum	1 place / 15 m^2 of ser. area	Minimum** Maximum*	**1 pl./ 24 m^2** **1 pl./ 15 m^2**

* – in many European countries instead of minimum parking standards – maximum standards are applied.

** – minimum standards can be feasible only if effective online services are applied.

The author also counted possible land use savings (Table 4.9), which would be feasible if changes in parking regulation were implemented. The maximal optimization of the area necessary for car parking in proportion with total area necessary for the object would be near objects providing elementary and advanced shopping and commercial centres, where this proportion with help of virtual mobility can be decreased from 0.41 to 0.32 (and this is equal to 22% of saved parking and land for the whole object proportion if one-storey buildings are developed is and 29% lesser space necessary for parking.

Table 4.9. Supposed savings in land use

Object	Useful area, m^2	Parking area*, m^2	Proportion of overall and parking area**	Suggested parking area, m^2	Suggested proportion of overall and parking area	Rate of changes, %
Offices, administrative enterprises	1000	800	0.44	560	0.36	18
Shopping and commercial centres	1000	680	0.41	480	0.32	22
Near restaurants and coffee houses	200	280	0.58	200	0.5	14

* – area for one parking place is carried as 20 m^2, whole area is counted following existing parking regulation;

** – proportion e. g. 0.44 shows the parking area share in overall construction area

Great optimization of area necessary for the car parking in proportion with total area necessary for the object would be near administrative, financial and public objects (banks, universities, business centres etc.) providing advanced services, where this proportion with help of virtual mobility can be decreased from 0.44 to 0.36 (and this is equal to 18% of saved parking and land for the proportion of the whole object if development is one-storeyed and 30% lesser space for parking.

The obvious optimization of area necessary for car parking in proportion with total area necessary for object would be near leisure and recreational objects providing specialized and specific services (like theatres, spa, restaurants and etc.), where this proportion with help of virtual mobility can be decreased from 0.58 to 0.50 (and this is equal to 14% of saved parking and land for the proportion of the whole object if development is one-storeyed and 28% lesser space for parking.

Such savings could be achieved only after implementation of comfortable online services in all below mentioned institution, friendly transport infrastructure (accessible PT, cycling routes and parking (Table 4.10) and with more accurate attitude towards planning of social infrastructure, which itself is quite a challenge as there are no such regulations in nowadays technical requirements for city's functional zones.

Table 4.10. Suggestions for bicycles' parking regulation

Where applied	Existing quote	Existing quota for cars parking	Suggested quotas for bicycle parking
Near offices, administrative enterprises	Not applied	1 place / 25 m^2 of ser. area	Minimum 1 st. / 200 m^2
Near educational institutions	Not applied	1 place /6-40 pupils (depends from institution status)	Minimum 1 st. / every 50 children, pupil, student
Near shopping and commercial centres	Not applied	1 place / 30 m^2 of ser. area	1 pl./ 250 m^2
Near theatres, cinemas	Not applied	1 place / 6 vis. places	Minimum 1 st. / 150 vis. places and minimum 4 st./per building if there are less than 600vis. places
Near restaurants and coffee houses	Not applied	1 place / 15 m^2 of ser. area	Minimum 4 st./per restaurant or coffee house

Suggestions for bicycles parking near institutions were prepared comparing proportion between trips done by car and bicycle as well as evaluating the size of virtual trips which substituted physical trips by bicycle for particular purposes (find more in ch. 4.2.4).

Following to the data obtained (see ch. 3 and ch. 4.2) the main conclusions about citizens needs were drawn and laid down in the scheme for social infrastructure zones and walking, cycling routes planning (Fig.4.6). In this scheme the main principles of planning social infrastructure according to the virtual mobility data are drawn.

The entire area is divided into three zones. The first one with smallest radius of accessibility R = 600 m is zone of elementary services with objects (named ESH in fig.) of very basic services (like food and daily goods, kindergarten). According to virtual mobility data, respondents start to avoid such trips when one way distance exceeds 0.8 km. To the second zone belong frequently used objects providing more advanced services (ESE) like bigger shopping alternatives, the choice of manufactured goods, occasionally needed financial and domestic services. The radius of accessibility R = 800 m was chosen following the same principle – avoidance of physical trip via Internet or mobile phone. The third object and prezone in this scheme – open public places (PP) like parks, squares, basic sport equipment and etc. This, according to social respondents needs, has to be at least in R = 1000 m distance from living place. As it is not always wanted to be reached on foot to (e. g. carrying children) PP must be connected with living place with PT transport and cycling routes (see in Fig. 4.6).

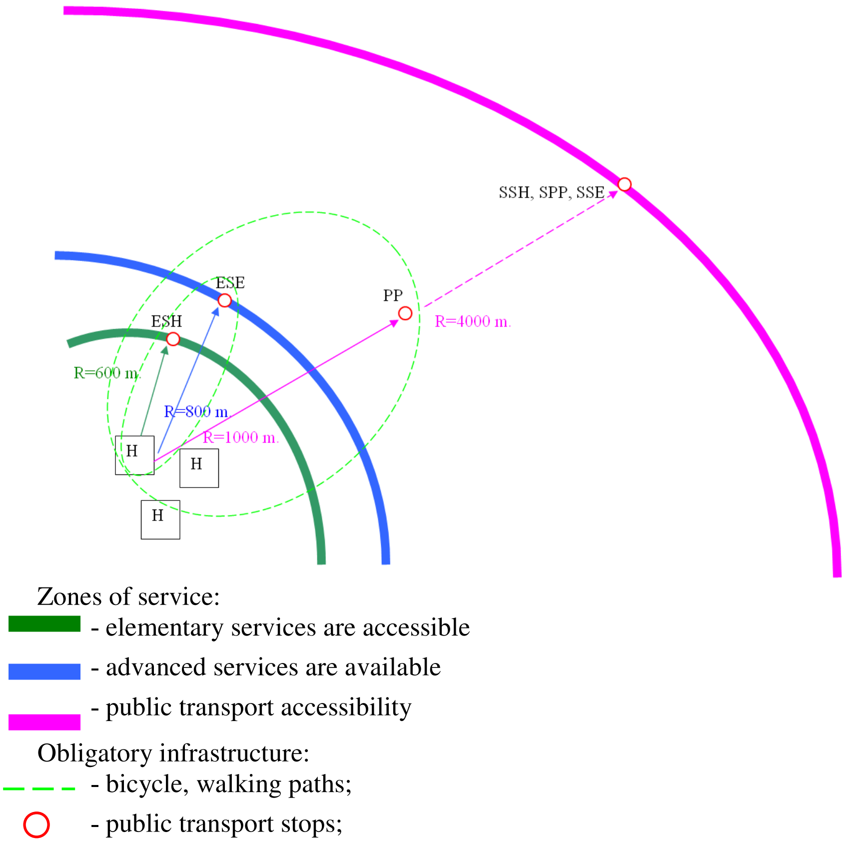


Fig. 4.6. The scheme for social infrastructure zones and cycling routes planning

And the last but not the least – zone of PT accessibility. In this zone, which according to the respondents behaviour must be in zone of R = 4 km radius, objects with more specialised and specific services (SSH, SSP, SSE) must be laid down. That would be special commercial places SSH, specialized services for the most of episodic needs SSE (chapels, clinics, banks, public institutions, arts schools and etc.) and specialised leisure centres SSP (spa, cinemas, stadiums, sport clubs and etc.). If that would be provided within 4 km distance from target group living place – all above mentioned land use and urban engineering questions would be even more possible to achieve (including car usage decreasing).

4.4. Conclusions of the fourth chapter

1. For the proper indication of the problem and for possible monitoring of mobility management results constant data collecting is necessary. In Lithuania it is advisable to arrange continuous monitoring of population mobility indicators in the database. Hereby authoress suggests for mobility monitoring to use practice from particular virtual and physical mobility research and data collecting process. If suggested data monitoring system is established, it will be possible to relate information observed to the needs of population for transport and social infrastructure as well as forecasting of such means for meeting the citizens' needs.

2. The author had designated that mechanism for legal mobility management integration and thus virtual mobility data usage in the land use planning process exists and virtual mobility data could be adopted in transport infrastructure plans, social infrastructure plans, parking regulation through BTR.

3. The author named main mobility management integration into urban planning principles and adopted them into different according their purpose recommendations. Those also follow different sustainable development principles. Recommendation A realizes a policy of poly-centric urban structure and maximum parking standards; recommendation B realizes a policy of medium and high land-use densities with a mix of different uses; recommendation C realizes a policy of concentrating trip generating development along PT corridors; recommendation D realizes a policy of transport impact assessment and recommendation E realizes a policy of re-use of brown field sites. In terms of sustainability each of recommendation' embodies particular sustainable development principles: ensuring life quality (A), decreasing car usage (B), increasing PT (C) and non-motorised transport (D). Recommendation E is encouraging economical and material resources saving.

General conclusions

The attention paid to mobility data and mobility management integration into the most important urban engineering processes so far is minimal, therefore virtual and physical mobility research was done within this doctoral work. Based on results scientific and practical conclusions of doctoral thesis were prepared:

1. There were defined the **concepts of virtual mobility and virtual trip**, highlighting differences between virtual activity and virtual trip in the doctoral theses: virtual trip is only that activity, when with the use of Internet or mobile phone one can directly avoid physical trip. Here virtual mobility is entirety of factors illustrating number of virtual trips per day, purposes of trips and characteristics of substituted physical trips.
2. The author created theoretical model for virtual mobility research, describing all stages of effective virtual mobility research: definition of target research group and its sample, characteristics of multicriterian and statistical analysis.
3. Using method of multipurpose analysis the most important economical factors, influencing traveling choice and preconditions for physical trips to be substituted with virtual trip are – duration of the trip (the objective significance: 61% of decision depends on the duration of the trip) and price (the objective significance: 28%). The most important social factors (and its significance) influencing number of physical or virtual trips were

determined using Clementine algorithm (the age of respondents and weekday). Significant differences among respondents according their living place were estimated too.

4. The most frequently made are work and studies related trips (41.4% from the whole sample), shopping trips (19.3%) and daily (e. g. paying bills) trips (11.1%). Trips substituted by virtual trips would have been made by car mostly – leisure trips (47% of virtual trips sustituted car). Virtual trips "saving" longest distances (average – 52 km) are socializing or work-studies related virtual trips via E-mail and Mobile phone.
5. It is advisable to consider virtual trips not only as the measure of mobility management but also to use it for regulation of transport infrastructure planning norms and density of urban development, that's why the author had suggested to complent existing BTR 2.06.01:1999 „Communication systems in cities, towns and villages": to minimize the number of parking spaces near shopping centers; public institutions; leisure and recreational centers after considering the extent and possibilities of virtual mobility in the concrete site. The author based on research results had estimated and suggested necessary bicycle parking norms and pointed out at the obligatory public transport stops near public and commercial objects, providing episodic services.
6. It is advisable to consider virtual trips as indicator of residents' social needs – based on research data authoress suggests principles for specific social infrastructure zones in the area. Cycling and walking paths have to connect living place and nearest recreational and leisure complexes. The optimal length of such path would be $L = 2.5 \pm 0.5$ km. The author also provided hypothetical suggestions for reviewing obligatory norms in BTR 2.02.02:2004 „Public buildings" and Lithuanian Hygiene Norms HN 32:2004 „Working with Videoterminals. Requirements for Safety and Health" regulating minimum area for work place, common used spaces and parking spaces for visitors and employees near institutions and offices.
7. The author prepared recommendations for urban engineering according to the main urban development principles and sustainable development criteria: A – recommendation ensuring life quality, based on policy of poly-centric urban structure and maximum parking standards; B – recommendation ensuring car usage decrease, based on a policy of medium and high land-use densities with a mix of different uses; C – recommendation ensuring increase of PT usage, based on a policy of concentrating trip generating development along PT corridors; D – recommendation ensuring increase of non-motorised transport usage, based on a policy of transport impact assessment; E – recommendation encourag-

ing economical and material resources saving, based on a policy of re-use of brown field sites.

8. Not all virtual trips can change, are changing or influencing physical mobility (71.8 of all virtual trips). In terms of urban and transport planning the most effective are all virtual trips related to virtual services – e-shopping, e-government, e-banking and surely teleworking. Research results proved that purposeful virtual trips can decrease to 10% of physical trips made by car to concrete objects and this is on the average 10 kilometres and 25 minutes saved per each trip.
9. Virtual trips can help optimize the land for construction needed and construction area as well. The maximal optimization of area necessary for car parking proportion with the total area necessary for the object would be near objects providing elementary and advanced commercial centers, where this proportion with the help of virtual mobility can be decreased from 0.41 to 0.32, near administrative, financial and public objects (banks, universities, business centers etc.) providing advanced services, where this proportion can be decreased from 0.44 to 0.36 and near episodic needs objects (restaurants, theatres etc.) where this proportion can be decreased from 0.58 to 0.5.

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Appendices

Appendices are given in attached CD:

Appendix A. The examples of diary 2006–2007 and 2008 (Lt, En).
Appendix B. Statistical results (printouts of tests and summarised results).
Appendix C. Multiple criteria evaluation of the travelling alternatives.
Appendix D. Mobility data base 2006–2008.

Kristina Gaučė

VIRTUALAUS IR FIZINIO GYVENTOJŲ MOBILUMO SĄVEIKA,
JOS ĮTAKOS MIESTŲ PLĖTRAI TYRIMAS

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INTERACTION BETWEEN VIRTUAL AND PHYSICAL INHABITANTS'
MOBILITY AND RESEARCH OF ITS INFLUENCE ON URBAN DEVELOPMENT

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