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IMPORTANCE OF VIRTUAL TRIPS FOR TRANSPORT INFRASTRUCTURE PLANNING

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Abstract. Limited possibilities of transport mobility, low quality and high prices of services induce local (change of living or working place) or virtual (e-work, e-government, e-shopping, e-communication) mobility of citizens. Despite the increased possibilities to avoid transport trips, street jams, pavement deterioration, the number of traffic accidents have been continuously growing. For this reason the research was carried out to define a possibility of physical trips (their purpose, length, transport mode) to be replaced by 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 a more effective plan of the land-tenure of transport and social infrastructure and to optimize new construction.

Keywords: physical mobility, virtual mobility, virtual trip, travel diary, territorial planning, transport infrastructure.

1. Introduction

According to *State Enterprise "Regitra" "Statistics of Transport Registration"* 2002, 2005 and 2008 years and *Dept of Statistics to the Government of the Republic of Lithuania "Number of Habitants"* 2002, 2005 and 2008, motorization level in Lithuania has been rapidly increasing; if in 2002 there were 340 cars per 1000 inhabitants, in 2005 this number came to 426, in 2008 – even to 506. Associated with this increase in car ownership, most of Lithuanian cities now face a range of environmental and problems, including increasing city-centre congestion, high accident rates and a general worsening of environment quality. Unfortunately, these problems have arisen as an outcome of too small supply of transport infrastructure and low quality of traffic organisation. Such solutions like episodic reconstruction or building of intersections, streets, new structures not only fail to solve the above-mentioned problems but even worsen them: during such reconstructions the traffic is paralysed 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 owners of land to be taken off are involved and it enables solution to be operative and big demand for investment, which finally does not lead to an expected benefit.

According to Juškevičius *et al.* (2008) and other town engineering scientists, mobility is the main paradigm in town planning and urban territories are under rapid development at the moment. This attitude had been developed by other scientists in the 70's already (Banham 1969; Berry 1970), predicting mobility changes in time and space according to new development, "electronic" environment and new alternatives to cover citizens' needs. Transport infrastructure or communication systems planning is inseparable from social, demographic and economic interests of residents, and thus, when planning the town transport system, an analysis of these processes should be included (Burinskienė, Ušpalytė-Vitkūnienė 2006).

One of the main criteria for sustainable cities development – to have compact and functionally different land use in different citys areas (Burinskienė 2003; Juškevičius, Valeika 2007), reducing use of energy and meeting the demands of new residential with rationalization of land use (Zavadskas *et al.* 2009). Based on multipurpose evaluation of Vilnius City residential areas (Viteikienė, Zavadskas 2007), the most significant criteria for district to be sustainable are: workplace is close, clean air, no noise, and safety. According to the results of multicriteria complex proportional assessment of alternative ways of the trip (Jauneikaitė 2007) – indicators safety and influence to environment appear to be the most significant when choos-

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ing trip by Internet instead of other ways proposed. All the mentioned facts and presumptions raise a new attitude to citizens' needs and ways to satisfy them. So more recently, there has been a move to explore other solutions, in the form of softer alternatives (mobility management) rather than structural improvements while planning the infrastructure for communication.

So far, Lithuania has no information base neither of physical nor virtual mobility. Another problem is related to inadequate attention to the mobility needs of target groups and individuals, also to mobility management in planning new transport systems or to transport connections in preparing new urbanization projects. Therefore, the main objective of this article based on the results of research carried out by the VGTU to determine, how physical mobility is changed because of virtual mobility impact and to suggest a reasoned way, how to use the above-mentioned information in urban and transport infrastructure planning.

2. Population mobility

The main object of research described in this article is population mobility. Therefore, before starting analyzing specific features of population mobility, its management and integration into transport and territorial planning, it is important to describe the main definitions used in this article.

Population mobility in the city is characterized by the frequency, duration, length, cost of trips and the spread of trips in a definite urban space, social, economic and other environment (Juškevičius 2004). In the context of this article the following types of mobility are important:

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 destination (min/trip), distribution of prevailing transport modes (%) etc. In this article 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 min) 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 m, action taken in direct way to someone's destination.

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 (PT) (bus, trolleybus, mini-bus, taxi, suburban bus, train) and by unmotorized transport (on foot, bicycle).

Virtual – a word used to describe a scenario where electronic means are used to simulate a traditional (physical) way of doing things. In *The Virtual Mobility Knowledge Base* a virtual mobility refers to the use of the new information and communications technologies (ICT) as an alternative to physical mobility 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 such an 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. Usually virtual trips by their purpose are divided into 3 major groups: e-work, e-business and e-commerce and e-services.

Such interpretation of virtual and physical trips allows us to formulate correct questions related to the replacement of one trip with another and to make unbiased comparison of the results obtained.

2.1. Virtual mobility

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 2 alternatives to satisfy the required pace of life – local mobility (the change of working and living place) and virtual mobility – communication means independent of transport system (Juškevičius *et al.* 2008).

The mobility, its measures and the main measures for management of mobility were discussed widely in European literature. Finally those were identified by MAX (2007). One of them is telecommunications. Such measures are usually initiated by organisations and others to reduce the need to travel by substituting telecommunications (such as teleconferencing, home shopping, or re-arrangement of working hours) for travel, or reorganising working practices, or both. This helps to reduce passenger flows towards certain attraction centres up to several times, but in order to achieve this it is necessary to know the target groups, the mode of transport and the distance they travel to a certain object.

A number of studies have projected the impact of online working and services on traffic. The most optimistic *Autoglass* project in USA on 1996 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. So whatever we name virtual mobility – mobility type or physical mobility management measure, 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 mln per year, commute hours could be reduced by 40 000–75 000 per year in Cambridgeshire County (a *recent DETR study conducted by The Home Office Partnership, Hague Consulting Group in association with Cambridgeshire County Council*);

– 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- & videoconferencing – 20% less business traffic and a total of 3% less traffic (MAX 2007).

Lithuania has no information base of virtual mobility. According to *TNS Global Market Research Specialists,* the number of Internet users (using Internet at least once a week) has increased up to 37% in 2008, if compared to 27.7% in 2006 (of the surveyed 15–74 year-old residents throughout Lithuania). In 2007, the 35–74 year-old respondents made 35% of the total number of the surveyed Internet users; in 2008, their proportion has increased to 40.1% 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% of the students had a possibility to use Internet at home. Of course, usage of the Internet (e.g. entertainments on the Internet) evidently does not reduce traffic flows. That's why the main objective of this article is to determine how physical mobility is changed because of virtual mobility.

3. Methodology of research in population mobility

The environment of social problems, especially those related with implementation of sustainability in any area, is directly related with science. It connects real world, data, theory (model) for solving particular problem (Burinskienė, Rudzkienė 2009). Research of transport market is unbiased and systematic data collection, recording, analysis, determination of patterns and presentation of information which plays the leading role in taking decisions on the basis of analytical information. Market research helps to take marketing, realization and strategic planning decisions. Basic methods of naturalistic research are the surveys based on questionnaires or telephone interview.

The following methodology was chosen for the research described in this article Fig. 1.

3.1. Research objectives and object

According to results of various definitions of sustainable development concept and its definition (Shen *et al.* 2007), the main aspects – economical and social sustainability - can be ensured maintaining capacity to meet the needs of future generations. So the main objective of this article – based on the results of research, carried out by the VGTU to determine how physical mobility is changed because of virtual mobility impact and to suggest a reasoned way how to use the above-mentioned information in urban and transport infrastructure planning.

The previous surveys showed that young (16–30 years) (Burinskienė, Jauneikaitė 2005, 2006) people are not only the most active IT technology users, but also the less mobile group of the society in a sense of transport trips. Therefore, 20–25 years old students were selected for a three-year sociological survey for evaluating the extent and the importance of virtual mobility within this group. This group were selected not because they are supposed to have a larger virtual activeness (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% 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 use is relatively high and increasingly disproportionate to other groups (based on data of 2008 survey, 42% of students has an access to private cars and use them as drivers for daily trips).

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 comparison purposes, in the year 2008 the adult residents of Vilnius City were also questioned, their diaries were especially useful for the analysis of dependency of population mobility on age.

3.2. Research methods

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 4 diary designs have been primarily used:

– travel diaries collect information solely about the trip (destination, departure and arrival time, mode(s) etc);

– 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 if not to ignore travel to record only one aspect of travel;

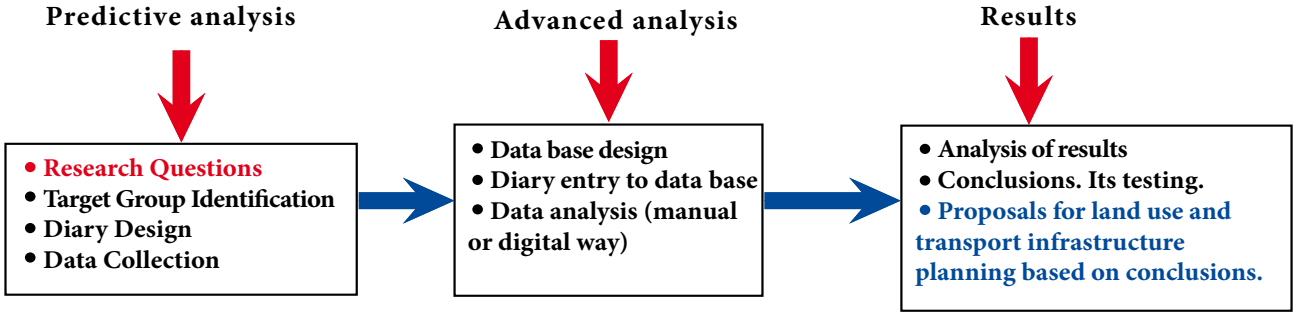


Fig. 1. Sequence of research methodology

– communication diaries record not only the activity of communication but also the time and mode of communication.

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. The survey results were analysed with 95% probability and 1.9% error. Preliminary analysis of this data by the authors found an increasing use of the internet and decrease in number of physical trips made, suggesting an association between the 2 variables, but an inability to establish 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 (Table 1).

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 much 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.

In contrast to typical practice (virtual trips are divided into 3 major trip purpose groups: e-work, e-business and e-commerce and e-services, e.g. *The Virtual Mobility Knowledge Base)* authors divided the types of virtual trips into 10 classes. Such a diary structure (Table 1) 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.

3.3. Data processing and analysis with the help of SPSS (Statistical Package for the Social Sciences) software

For a qualitative analysis of available data the SPSS software was selected and the specially adjusted for this software Clementine's rule induction algorithm (Clementine 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 (Brewer, Khabaza 2000).

Decision trees fall into the category of data mining tools called classifiers, which are especially useful in differentiating the parts of population (Korab 1997), like in this research differentiating those groups which are the most likely to do a physical or virtual trip. The aim of analyzing data with the help of answer tree model was to check

Table 1. Fragment of the diary wording started to be used in 2008

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 by 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.						
Internet services	**Time taken**	**If You have no access to telecommunications would You:**	**YES**	**M**	**T**	**D**
Search for information for studies/work		*go to library?*				
Ordering 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.) chartrooms		*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)						

various assumptions about different respondent groups, different number of their physical and virtual trips, their purpose, selected transport mode etc. This model analyses only the statistically significant ($p > 0.05$) and very significant ($p > 0.001$ results). Results are presented in a graphical form (Figs 2, 4), in a descending order of significance from statistically the most significant factors on the top to less relevant on the bottom.

In order to carry out a correct analysis in a quantitative sense, it is enough to have a representative sample of data cleaned from logical mistakes (in this case the diaries of more than 1000 respondents have been analyzed). This data sample is sufficient (the number of respondents necessary for a reliable survey in this case was 390) to make an unbiased evaluation of the percentage distribution of certain features of respondents and their trips, frequency of recurrence etc. However, this data is not enough for a qualitative data analysis (for example, for the forecast based on de facto data), because the sequence of years (2006–2008) is too short. Thus, the below research results in many cases is a quantitative expression and hypothetical interpretation of available data.

4. Results of population mobility research

4.1. The main predictors as to whether and why respondents made a physical trip

The aim of analyzing data of mobility diaries with the help of answer tree model was to identify specific features of respondents' mobility and their social features significant for selecting of trips and giving attention to only those factors that are significant for the selection. When analyzing peculiarities of physical and virtual trips, the main studied predictors were: year of survey, living place, weekday, age, income, car access, Internet access. However, the answer tree model has defined that the only factors significant for selecting the trip are: gender, age, weekday and year of survey (Fig. 2).

Since the sample of the respondents (who made at least one physical trip per day) is respectively large ($N = 899$), they were divided into 2 groups: those who made 1–3 trips per day and those who made more than 3 trips. Thus, the main predictor determining the number of trips made (1–3 trips or more than 4 trips (+ 4) was related to the day of week, with those people making weekday trips significantly more likely to report making 4 or more trips ($\chi^2(1, N = 899) = 27.58$, $p > 0.001$) compared to those making trips on weekends. For those making weekday trips, over 35 were significantly more likely to report making 4 or more trips ($\chi^2(1, N = 815) = 10.36$, $p > 0.001$) compared to under 35. For over 35 making weekday trips, females were significantly more likely to report making 4 or more trips ($\chi^2(1, N = 125) = 7.12$, $p > 0.001$) than males. For under 35 making weekend trips, people in 2006 were significantly more likely to report making more than 4 trips, compared to those in 2008 ($\chi^2(1, N = 690) = 8.84$, $p > 0.05$). The main conclusion made from the analysis of physical trips in a period 2006–2008 is: students are not the most mobile target group, they make less trips than the

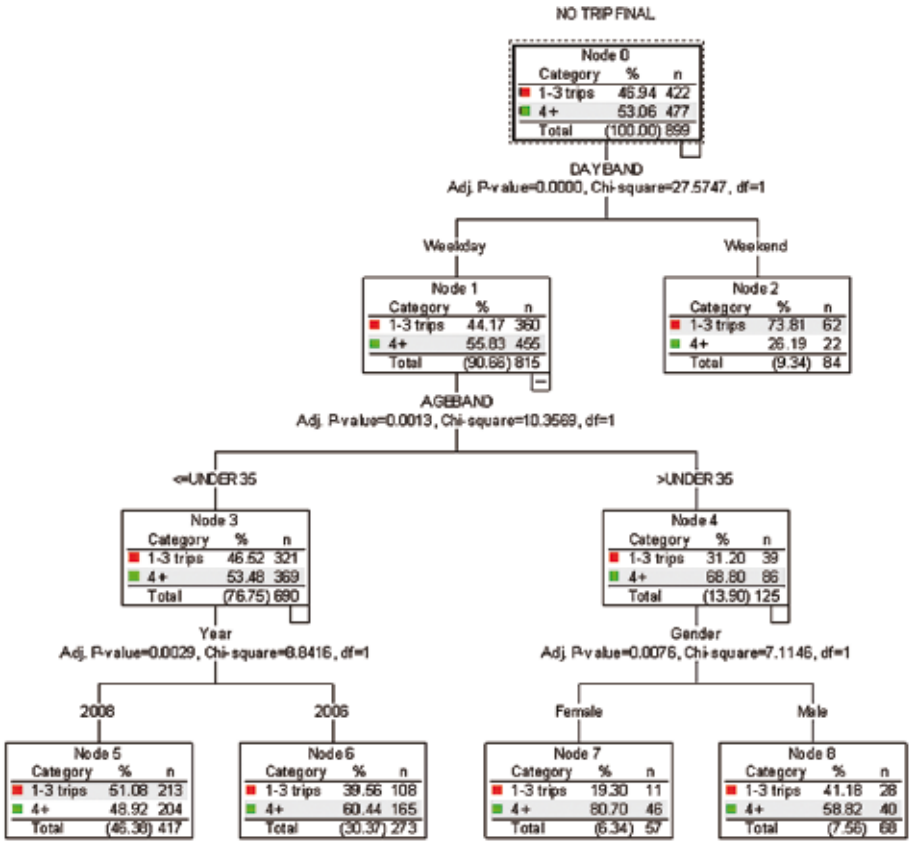


Fig. 2. Answer tree – what conditions influence the number of physical trips per day?

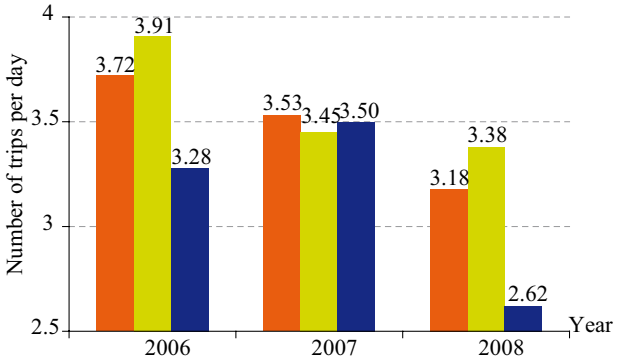


Fig. 3. Average number of trips made per day (■); respondents living off the campus (■); and in the campus (■)

35 year-old and older respondents (results of adult survey has been also included, Fig. 3) 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 did not name predictor "living place" as significant).

4.2. The main predictors as to whether and why respondents made a virtual trip

It was determined that for selecting the virtual trip significant factors are: age and weekday (Fig. 4). The main predictor as to whether respondents made a virtual trip or not, concerned their age, with under 35 significantly more likely to have made a virtual trip ($\chi^2(1, N = 654) = 203.86$, $p > 0.001$). The number of under 35 who made trips was also dependent on the day of week, with significantly more people reporting making virtual trips on weekdays ($\chi^2(1, N = 529) = 6.1$, $p > 0.05$) compared to weekends.

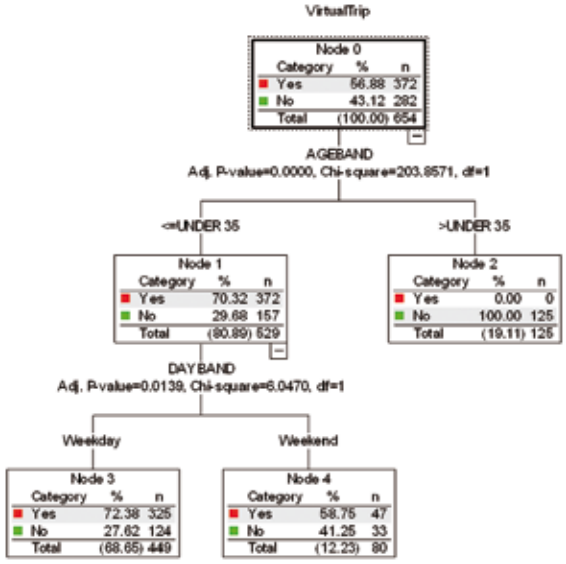


Fig. 4. Answer tree: what conditions influence whether virtual trip was made?

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 (Figs 5, 6).

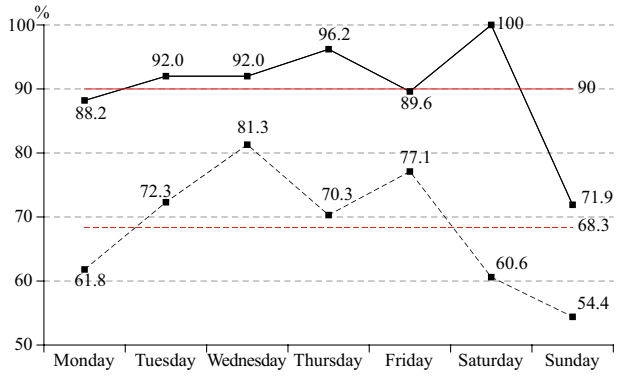


Fig. 5. Physical and virtual mobility during a week – percentage of respondents who made at least one (physical or virtual) trip per day: —■— – physical trips; —— – average of physical trips; - -■- - – virtual trips; - - - - – average of virtual trips

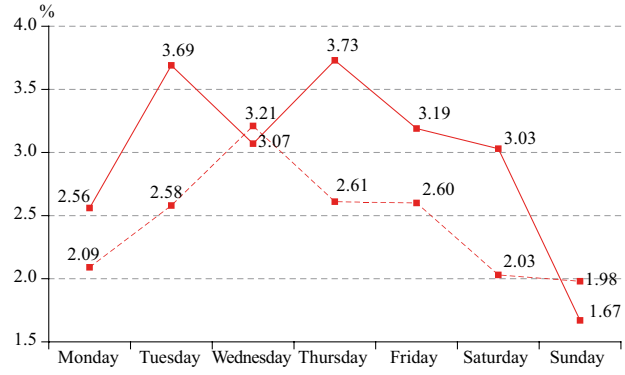


Fig. 6. Physical and virtual mobility during a week – average of physical (—■—) and virtual (- -■- -) trips per day

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. However, statistics on the trips of the end of the week shows that e.g. on Friday, when the respondents are less mobile (almost 11% of respondents makes not a single trip), virtual mobility is nearly peak, if compared to other week days (only on Wednesday at least one virtual trip is made by 4% more respondents). And on the contrary – on Saturday, when all the respondents make at least one physical trip (the average – 3.03 trips per Saturday, Fig. 6), virtual trip is made only by 60% of respondents (the average of the week's mobility – 68.3%), the average of trips decreases up to 2.03 (if compared to the peak – 3.21 and the average – 2.44). This suggests an additional assumption – according to their purpose part of physical as well as virtual trips are unchangeable and must be made irrespective of theoretically influencing outside factors. However, if the resident has a possibility to choose the mode for his trip, a certain mode of his physical trips can and is replaced by 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.

4.3. Replacement of physical trips with 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 (Figs 7, 8).

Fig. 7 gives the systemized results of physical trips where "PT" shows all the trips made by trolleybus, bus, mini-bus, private bus, train; "Car" – by office car, by car as a driver and 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.

Fig. 8 gives the structure of trips made by the respondents per day.

It is evident that the number of trips that can be replaced with virtual trips has been slightly decreasing, i.e. during 2 years (data of 2007 is not included) the percentage of work-related trips as well as shopping trips has decrease by 0.5 and 2.1% respectively from the total structure, almost by 6% from the number of work-related trips and almost by 17% from the number of trips made for shopping. This allows to make an assumption that the number of these trips has decreased after they were replaced with virtual trips.

In summary, this analysis forms some new assumptions for further research:

– part of virtual trips takes away the flow from public transport; however, we need to find out those virtual trips that would help reduce the number of trips by private car;

– most likely, the virtual trips replace part of work-related trips and household (shopping) trips.

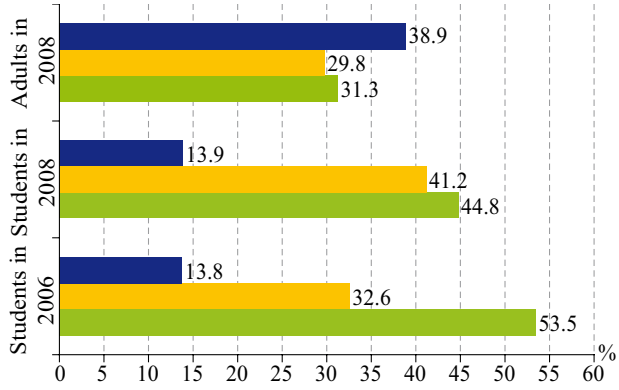
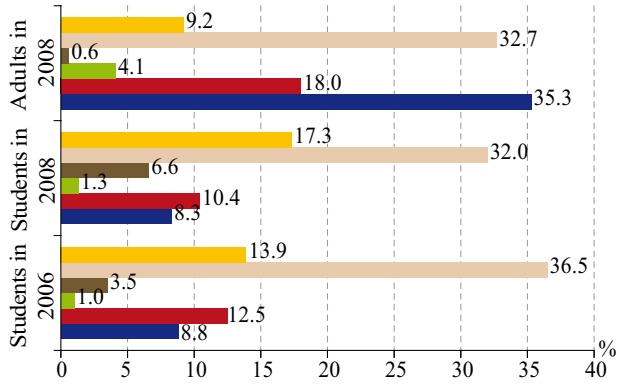


Fig. 7. Comparison of students and adults trips by mode: ■ – PT; ■ – car; ■ – friendly trip



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

Fig. 8. Comparison of students and adults trips by purpose: ■ – work and work-related; ■ – shopping; ■ – health related; ■ – other; ■ – home; ■ – leisure

In order to check the above assumptions, the analysis of virtual trips was carried out by their purpose (Fig. 9) and by the replaced transport mode (Table 2).

One can see that ordering food and other goods replaces physical trips by almost 100%. 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 (Table 2).

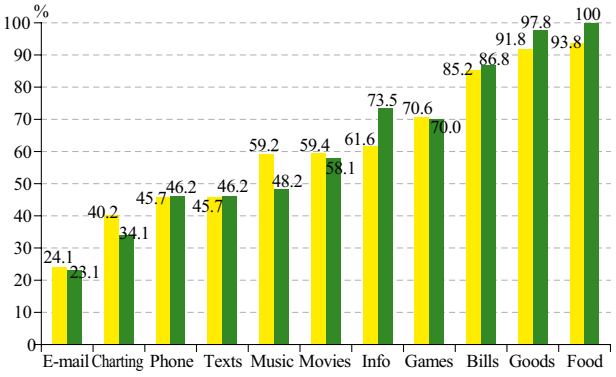


Fig. 9. Whether virtual activity replaced or not a physical trip (■ – respondents living off the campus; ■ – respondens living in the campus)?

Table 2. Physical trips replaced by virtual ones

Activity – ordering and(or) buying manufactured goods (147 reported positively)		Total sample using each mode, %	Time, min	Distance, km
Mode replaced – Car	Driver	22	24	14.1
	Passenger	5	5	9.3
Mode replaced – PT	Trolleybus	24	23.3	7.9
	Urban bus	10	60	11.5
Mode replaced – walk/cycle		39	37	1.6
Activity – ordering and(or) buying food (117 reported positively)		Total sample using each mode, %	Time, min	Distance, km
Mode replaced – Car	Driver	29	26	7.7
	Passenger	7	31	9.1
Mode replaced – PT	Trolleybus	25	45	6.0
	Urban bus	11	36	9.9
Mode replaced – on foot/cycle		27	19	2.2

The results are evident – 17% decrease in the number of shopping trips, averagely 30% of these trips would be done by car, the average duration of these trips 20–25 min, distance – about 10 km.

5. Proposals and conclusions

In 2008 the number of Internet users (using Internet at least once a week) has increased up to 37% (of the surveyed 15–74 year old residents throughout Lithuania). In 2008 every second 39–65 year old Vilnius City resident used the Internet everyday, whereas, in the same year nearly 95% of the students had a possibility to use Internet at home and made on average 2.5 virtual trips per day. This shows rapidly increasing usage of Internet among all various target groups.

The obtained results show that the average number of trips made by students has been continuously decreasing from 3.72 trips/day in 2006 till 3.18 in 2008, comparing with adults doing on average 4.36 physical trips/day. Having in minds the aim – to meet the needs of future generations, these results allow us to think that the target group was chosen correctly.

The obtained results show that most likely the virtual trips replace part of work-related trips and household trips. Averagely 30% of all daily needs trips could be substituted. It provides an assumption for further research indicating how these results could be applied in land use and transport infrastructure planning.

Averagely 10% trips done by car, the average duration of these trips 20–25 min, distance – about 10 km are likely to be substituted with virtual trip and this information on the decreasing number of shopping trips should be used for regulating parking places at the shopping centres.

Averagely 10% trips done by public transport, the average duration of these trips 20–25 min, distance – about 9 km are likely to be substituted by a virtual trip and this information should be used for planning public transport routes with attitudes to main target points which are avoided and replaced with virtual trip possibly because of insufficient PT supply.

Averagely 12% trips done by non-motorized transport (bicycle, on foot), the average duration of these trips of 30–35 min, distance – about 1.5 km are likely to be substituted with virtual trip and this information should be used for planning non-motorized transport infrastructure (optimization of bicycles and pedestrians paths, bike parkings).

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