SSE RIGA

SSE Riga Student Research Papers
2014 : 2 (158)

TIME IS LITERALLY MONEY: A COST AND BENEFIT ANALYSIS OF INTELLIGENT TRANSPORTATION SYSTEM PROJECTS IN VILNIUS EMPLOYING VALUE OF TRAVEL TIME ESTIMATION

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ISSN 1691-4643
ISBN 978-9984-842-78-3

November 2014
Riga

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Abstract

The study seeks to determine whether implementing a public transport priority system in the capital city of Lithuania, Vilnius, is economically beneficial, by estimating the benefit to cost ratio of investing in intelligent transit technologies. The authors conducted a multiple stage study: 1) interviewed public transport management company representatives in the two largest Lithuanian cities, Kaunas and Vilnius, to determine the current progress and potential willingness for implementation, 2) surveyed the citizens of Vilnius and developed a value of travel time (VTT) estimation model, using multinomial logistic regressions 3) estimated the benefits in terms of monetized time savings in two most loaded public transit routes and weighed them against the costs of the investment. The estimated VTT for Vilnius is 2.02 EUR per one hour of travel time saved and the benefit to cost ratio is 1.09. The research proposed a VTT estimation model for the case of Lithuanian cities, as well as provided an example for cost and benefit analysis by employing time savings, which had not been used for transport project appraisal in Lithuania before.

Keywords: ITS, VTT, CBA, public transport, Vilnius

Acknowledgements

We would like to express our gratitude to our supervisor Sergejs Gubins for his guidance and critique throughout the course of the study. Next, we are thankful to Paulius Keras for providing us with valuable information about the public transport situation in the city of Kaunas. Also, our gratitude goes to Anton Nikitin, representative of ME "Susisiekimo paslaugos", which provided us with all the necessary information and data about Vilnius public transport. We thank our peers for support and encouragement as well as feedback. Finally, we express our gratitude to our families for understanding and support.

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1. Introduction

Public transit development is in the center of attention in many municipalities across the world. The goal is to make it accessible to every citizen and working smoothly. One of the possible approaches to tackle challenges in urban transportation such as transport congestion, environmental impact as well as travel delays from schedules is the use of Intelligent Transport Systems (hereafter, ITS). These systems include, but are not limited to, location, traffic, motion and wireless sensors, their management hardware and software.

The end user encounters them when they check real-time travel information, plan an optimal route or experience shorter travel times due to efficiently regulated public transit. The systems work and interact with each other to facilitate management of transport and traffic as well as provide the opportunity to use the information to make more efficient travel decisions (The European Parliament and the Council of the European Union, 2010). A growing number of European cities use ITS and other technology-driven smart approaches to improve their transportation (Civitas, 2013a; Berg Insight, 2012). Analysis of smart public transport practices can produce valuable insights for municipalities and departments, which manage public transportation. The study is about the capital city of Lithuania, Vilnius, and analyzes possible improvements for public transport system development and management. The authors answer the following research question:

Whether ITS implementation in Vilnius is economically beneficial for the city's public transport system?

The study briefly overviews the types of technology that are adaptable to public transportation as well as the possible impacts of implementation. The authors also conduct interviews with representatives of transport management companies in two Lithuanian cities, Vilnius and Kaunas. This allows to comprehend what progress has been made so far as well as to understand the willingness of municipalities to introduce smart technologies into the urban transport infrastructure. Thirdly, citizens of Vilnius are surveyed and a value of travel time estimation model is built. And lastly, an analysis is conducted of the benefits and costs of implementing a technological solution to the city's infrastructure. Public transit priority system is assessed in two most loaded routes in the city of Vilnius, in order to determine whether time savings acquired from the implementation outweigh the costs related to it.

2. Literature Review

2.1. Economic Rationale for Public Transport

Society often takes mobility for granted: it has become vital to have access to transport, as every daily activity of a city inhabitant requires movement (Acharya, Parumog-Pernia & Morichi, 2013). This stems from the essence of urban structure: locations of goods and services are spatially distributed and highly specialized. As only a small fraction of trips is done for pleasure, transportation serves only as an instrument of achieving a desired objective. In this context, transportation becomes a cost that is incurred when performing almost any daily activity. The costs can be both direct and indirect; hence, the topic has to be put in a broader perspective of policy making and economic terms (Hanson, 2004).

Transport projects can affect such economic variables as employment, productivity, investment environment, real estate value or tax revenue. Economic development is stimulated by both improvements in accessibility and reduction of transportation costs.

When it comes to a narrower area of public transport, the projects can affect such economic variables as employment, productivity, real estate value or tax revenue. Economic development is stimulated by both improvements in accessibility and reduction of transportation costs. Investment and development of transport infrastructure receives a fair share of government spending. However, most of the benefits of the investment are indirect and will appear throughout time. This causes a problem in valuation of transport projects – as not only the benefits are hard to account for, there are possible indirect costs as well. A research, which has studied the possible public transit investments in Chicago confirms a strong economic rationale of such projects. Chicago Metropolis 2020 (2007) calculates the return on public transit investment and finds the lower bound value to be 21%, while higher bound (depends on the scope of the investment) might be 34% per year. Such evidence suggests that government spending on transport has a quantifiable value for the economy.

2.2. Current Problems

Congestion is one of the main problems that urban areas face. The Civitas Initiative (a think-tank established by the EU) defines congestion as an occurrence that is common in populated urban areas, when more people want to be in the same place at the same time than the transport infrastructure capacity allows. Such situations result in congestion costs, which, as defined by Grant-Muller & Laird (2006), accumulate delay, vehicle operating, environmental pollution and nervous distress costs. Consequently, as it leads to unproductive allocation of scarce resources, in terms of longer waiting time, it becomes a challenge to local and national governments to plan the infrastructure properly in order to avoid such excess of demand for travel over supply of road capacity (Van Egmond, Korver, Stemerding & Wefering, 2012).

The road mortality rate in the European Union was around 35,000 people in 2009, and more than 1.5 million people suffer from injuries due to traffic accidents. The rates of accidents vary across countries, with a lower accident rate in high-income countries, compared to low and middle-income countries (Van Egmond et al, 2012). Initiatives to decrease transport accidents and fatalities receive a fair amount of attention. In this area, public transit can be described as a very safe mode of travel. According to Fitzroy and Litman (2009), public transport has 50 times less fatalities per trip comparing to an automobile. The authors suggest that a mode shift towards usage of public transportation can have a significant impact on road safety. Moreover, Litman and Lovegrove (2008) show that improvement in transportation accessibility significantly reduces road accidents and improves overall safety.

2.3. Practical ITS Applications

The use of intelligent transportation systems has been gaining awareness and today it is on the agendas of many public policy makers. Promotion has been evident in both legislative and technological areas, while deployment follows general technological advancement (European Commission: Joint Research Centre, 2012; Research and Special Programs Administration: Volpe National Transportation Systems Center, 2000). Additionally, standardization of ITS application contributes by improving the technological lifespan and maintenance costs of an investment, communication between involved parties and creation of a competitive market (European Commission: Directorate-General for Mobility and Transport, 2013; European Commission: Content & Technology Directorate-General, 2013). This activity is especially evident in the USA, with the EU quickly catching up (Intelligent Transportation Systems: Joint Program Office, 2011; European Commission: Directorate-General for Mobility and Transport, 2011)

ITS can be defined as a network of synchronized intelligent technologies linked together. Well-organized relationships between units in the system enable automated data collection, analysis and its practical implementation (Public Information Office: City of Dubuque, 2013). Modern use of Information Communication Technologies (ICT) enables continuous management of information and facilitates effective use of all available resources in the transport area. The general advantages of ITS use in public transport contribute to a reduction in travel time and variability, wear and tear or stress costs. ERTICO (2010) describe some of the possible tangible goals of ITS usage for mobility, which include reduced amount of accidents and delays from schedule, decrease in environmental footprint, increase in the number of fully informed users, reasonably priced, safe and trusted services that respect individual privacy while using public services. A more recent successful ITS implementation goal has been added to the latter list: empowering individual users with information and incentive to extract value from crowdsourcing (Al-Yaseen, Ali, Ejaz & Javed, 2012).

ITS implementation creates challenges at technological and institutional levels. Technological solutions not only have to fulfill a specific task, but also be capable of various interactions with other technologies and be adaptable to future upgrades. At the institutional level, different agencies might not have the experience and necessary know-how for a mutual project at the beginning of ITS employment (Research and Special Programs Administration: Volpe National Transportation Systems Center, 2000). The EU also points to the unimodal approach towards smart transportation, which creates a substantial amount of unrealized opportunities. Meaning, only separate ITS components are implemented, without benefitting from the full system potential. This confirms the idea of commonly known and accepted standards to facilitate the use of such potential (European Commission: Joint Research Centre, 2012).

As ITS interconnects a variety of different transportation categories, it is usually classified by the parties affected. European Commission: Joint Research Centre (2012) suggests 8 ITS categories: (1) traffic and travel information, (2) traffic and public transport management, (3) navigation services, (4) smart ticketing and fee collection, (5) transport safety and security, (6) freight transportation and logistics, (7) intelligent mobility and co-modality services, (8) environmental and energy efficiency. This framework covers points beyond only public transport area, however provide a comprehensive view on available technologies.

a. Traveller information systems

Compiling all sources of schedule, traffic and real-time public transport data into one database not only allows organizing transit for the operator companies, but also carries significant benefits for the users. The purpose of traveler information systems is to provide public transport users with the necessary information to plan, carry out and alter their journeys beforehand or already on-the-move. An additional, yet critical, aspect of this process is the accessibility provided. Public transport information infrastructures that accomplish this gain a substantial competitive advantage in the eyes of IT-empowered users. This type of users appoints a high level of priority to use reliable systems with real-time updates, get internet access wherever they go and have a user-friendly travel experience (American Public Transport Association, 2012). Providing such experience has a substantial effect on promoting ridership and mode shift. As this is the primary goal of implementing ITS, travel information systems usually take the highest priority (Chowdhury, Dunning & Fries, 2011).

Real-time passenger information (RTPI) systems have been widely researched and evidence affirms that such initiatives result in ridership generation. Tang and Thakuriah (2012) present a comprehensive review of literature on the topic and the factors influencing such an effect, complementing the analysis with 8 year evidence from Chicago. Chowdhury, Dunning and Fries (2011) explain the impact by analyzing changes in traveler behavior, ridership generation, mode shift, in-vehicle travel time and out-of-vehicle waiting time, confirming the expected positive effect of RTPI on public transport usage.

b. Smart ticketing and fee collection

The implementation of electronic payment for public transportation via smart cards enables users to pay for the service more conveniently. Besides the increased comfort and incentive to use transit, electronic tickets minimize use of resources and facilitate revenue collection for the operator. Additionally, data collection and real-time analysis becomes feasible, providing grounds for further improvements in travel planning, route scheduling and demand management (Research and Special Programs Administration: Volpe National Transportation Systems Center, 2000).

c. Transportation demand management

The area of transportation demand management refers to the concept of maximizing capacity of the infrastructure. ITS use provides alternative transit information and accessibility for users. Carpooling promotion, park and ride service and high occupancy vehicle lanes result in maximum efficient employment of the existing infrastructure (Research and Special Programs Administration: Volpe National Transportation Systems Center, 2000).

d. Fleet and traffic management systems

Operators can utilize ITS to ensure a reliable and high quality fleet. Technologies that facilitate service demand management, traffic information, real-time location services and incident warnings enable more efficient transit. When having access to such data and its real-time analysis, public transportation can be planned and scheduled more efficiently, reducing the operating costs and improving reliability. By using road traffic management that includes intelligent traffic signal control and transport priority systems public transport can become more reliable and perform on time. All of the aforementioned means in turn result in more favorable users' opinion, increasing ridership and incentives for mode shift (Research and Special Programs Administration: Volpe National Transportation Systems Center, 2000).

An efficiently developed public transit priority system allows passengers to achieve time saving benefits. A study carried out in Dublin uncovered that public transit users are willing to pay extra amounts of money for large improvements in journey times (Convery, Ferriera & McDonnell, 2009). A rather large amount of cities around the globe have already started implementation of priority systems into public transit. London and Los Angeles being one of the most prominent examples, both the cities achieved reductions in journey time as well reduced delay variability in many cases (Danaher, 2010; Bretherton, D'Souza, Gardner, Hounsell, Shrestha, 2009). Researches sometimes disagree with the benefits that are gained because disadvantages inevitably rise to those who do not use public transit - their transit time might increase. Nonetheless, the documented increase in travel time for non-public transit users can be considered negligible (Bretherton et al., 2009).

2.4 Transportation Projects Analysis

Evaluation and analysis of transportation projects is a complex task. The difficulty stems from the variety of areas that an implementation of a project involves. Besides the observable economic effects, a transportation improvement touches many social and environmental factors, which are difficult to predict and estimate. The common practice in evaluating the impact of a transport project and choosing the best policy is a well-known cost and benefit analysis (hereafter, CBA). Over many years of research, transport area has become the classic example for performing this type of analysis. The approach is valued due to its applicability with a high number of affected parties and relatively little complexity of monetizing the benefits on social welfare (International Transport Forum, 2011).

The main principle of CBA is to make different type of effects, both benefits and costs, comparable in monetary terms. While project costs might be easily quantifiable, the benefits require complicated estimations. For instance, such analysis is performed to value the benefits of reduced travel time or improved reliability of the public transport (Small, 1998). The key approach to monetizing such benefits is the measurement of individual willingness to pay for the offered benefits. CBA does not attempt to calculate the overall improvement to the society from a specific project – the individual benefits are summed up together, and, when combined with occurring externalities, present a comprehensive appraisal. Hence, CBA has become the standard approach to evaluate both economic and socio-economic impact of the transport projects and will be discussed further as the main framework for the purpose of this research.

3. Methodology

The primary objective of the research is to weigh the costs of ITS implementation against the potential benefits and to understand whether the upgrade in the existing system would be advantageous to the city.

The authors analyze technologies specified by the Civitas initiative, which fall into the category of public transport enhancement via ITS. This category includes (1) location definition systems for real time information collection and delivery, (2) passenger information systems, (3) route planning tools and (4) sensors for priority setting at crossroads with traffic lights for public transit vehicles (Civitas, 2013b).

The methodology section is divided into four parts. The first part describes ITS and their effects in already implemented projects outside Vilnius. Second part introduces an analysis framework, the cost and benefit analysis, which will be the main tool to assess economic potential of such technologies. Third part covers travel time valuation, one of the most important factors for the CBA, and describes its use in the current study. The final part presents the fieldwork plan, which starts from the initial analysis of the city's transport infrastructure and finishes with the ITS implementation assessment results. Every fieldwork stage describes its process, relation to the next stage and the expected deliverables at the end of the stage.

3.1. Data and Information Sources

For information about the ITS infrastructure as well as the municipal governments' opinion about them, interviews were conducted with representatives of transport departments in two major Lithuanian cities – Kaunas and Vilnius. In Kaunas, a department within the municipality is responsible for managing all public transit related problems, whereas Vilnius has established a separate legal entity (however owned by the municipality) for the same purpose.

The Kaunas interview in this research is a pilot one. As it is the second biggest city in Lithuania which closely works with Vilnius and Klaipėda on public transport development projects, the authors chose to interview Kaunas to observe whether the positions regarding ITS are similar in the two cities, as well as to see whether there is a difference between the outlook towards ITS implementation.

The interviews were conducted individually with representatives of both cities – Paulius Keras, Director of Transport Department in Kaunas city municipality and Anton Nikitin, Smart City Project Coordinator, from ME „Susisiekimo Paslaugos“, the municipal company responsible for organizing public transportation in Vilnius. The preliminary interview questions and data requests were sent in advance, so that the interviewees would be able to prepare. The interviews were recorded for further analysis by the authors. The interviews, however, were face-to-face, therefore the questions were provided mainly as a guidance to what topics the authors will cover. More questions were asked during the interview to uncover in-depth information.

The interviewees were given a brief introduction to the topic of the research and were asked a number of questions about (1) ITS already implemented and the process of implementation, (2) evaluation of transportation projects, such as estimations and effect calculations and (3) additional questions regarding funding or cooperation with other municipalities. The data requested included, but was not limited to: investment costs, efficiency measurements or citizen satisfaction questionnaire results.

3.2. Intelligent Transportation Systems

First category of intelligent transportation systems is concentrated on information collection by sensors located both in urban areas and vehicles used for public transport (buses, trolleybuses). The sensors are part of a location definition system, which allows the transportation company to track the location of buses and estimate arrival times, and therefore take into account delays, traffic jams and other unexpected occurrences. It delivers them to a platform accessible by public transit users as well as to smart screens distributed in busiest stations. Provision of more information to users allows for more efficient trip planning and consequently results in time savings. Additionally, these systems improve travel time reliability, which is another recognized benefit among transportation projects. Several EU funded projects are already in place, with significant improvements – users are satisfied with the measures, awareness about public transport has increased (Metsvahi & Rannala, 2013; Pavlic et al., 2010). While the city of Vilnius has presumably implemented some of these information solutions already, the level of development is revealed by the qualitative interviews conducted with the city officials and management of the municipal transport company.

Another measure, which is implemented in several European cities, is public transit priority systems, specifically at traffic lights. Public transit vehicles can inform the system of traffic lights about their arrival to a traffic light and gain priority for crossing. This reduces the travel time and ensures schedules are met (Civitas, 2013b). Consequently, the level of development of traffic management in Vilnius is to be revealed after interviews and receiving statistical data.

3.3 Cost and Benefit Analysis

Cost and benefit analysis is an approach that is most commonly used by academics, city municipalities and country governments to evaluate an investment into the transport infrastructure. It allows to quantify and monetize the benefits that are a consequence of the investment, and weigh them against the costs of the project, in order to see whether the project will have positive impact or not. This method is preferred due to the fact that it provides a framework for monetizing potential benefits for improvements in different socio-economic factors, and allows to perform analysis with limited resources available and provide the best possible approximation (Damart & Roy, 2009).

Transport investment projects have several types of costs. Apart from the initial investment, especially in infrastructure improvements, such as building new roads or widening already existing roads, there are also land and property costs, as well as social costs involved. For instance, people can be moved out of their homes in order to lay down the road, or a new road obstructs the usual route of bicycle users. Nonetheless, an advantage of a ITS investment is the fact only the cost of the technology is taken into account while estimating costs for analysis. Thus, after determing the specific ITS implementation possibilities, costs will be calculated according to their installation, management and servicing costs.

The benefits in CBA are harder to define and quantify. The impacts from implementation of a project can be multifaceted and therefore affect more than one factor, especially in the case when factors are a function of one another – for example CO2 emissions are a function of congestion and vehicle usage – if vehicle usage and congestion decreases, CO2 emissions consequently decrease as well. Therefore, it is important to be careful when assessing which factors are impacted directly, and which indirectly, in order to make more precise estimates for the analysis and to avoid double-counting. As in transportation projects the highest share of benefits are attributed to traveler time savings, this method will be of primary importance when estimating benefits for Vilnius.

3.4 Value of Travel Time

The monetization of travel time becomes possible only after aggregating individual preferences into a set of group preferences and deriving the average value of willingness to pay. When it comes to aggregating, a high variability of values occurs. Such a result can be explained by many factors that influence the Value of Travel Time (hereafter, VTT). For instance, trips can have different purpose (work or recreational), different level of comfort (private or public vehicle), the individuals have different demographic and socioeconomic qualities (Victoria Transport Policy Institute, 2013). Depending on the scope of the research, average value of travel time can be quantified for both entire populations and specific subsets. That being the case, any analysis must first place emphasis on the extent of the proposed project in order to correctly select the groups of people affected (Perk, DeSalvo, Rodrigues, Verzosa & Bovino, 2011).

To apply the concept of VTT in Vilnius, authors choose not to use empirical estimations of VTT from foreign studies, but to estimate them for the particular case. This is preferred not only because of implicit differences in economic development, but due to the fact that every public transport system is highly peculiar. After reviewing the current public transport situation in the city and determining the possible ITS improvements, a sample of Vilnius citizens is selected to conduct the survey. Survey results serve as the data input for econometric estimations, resulting in a Vilnius-specific VTT that fits the requirements of the research. A detailed explanation of the study design and VTT estimation are presented in the following sections.

To check the correctness of VTT estimated by the authors, a number of researches have been reviewed. In these studies, VTT is linked with the average hourly wage rate in the analyzed area. From the reviewed sources, it is reasonable to state that an established rule of thumb is VTT accounting for 50% of the wage rate. A full summary of the studies can be found in Appendix 1.

3.5 Survey Framework

Survey-based analysis for transportation is a widely recognized and accepted method for transportation project appraisal since the early 1980s. Kroes and Sheldon (1988) review its early development and growing popularity among both governmental and scientific projects. The more recent review by and Bates, Burge, Rohr and Vuk (2004) confirms its successful implementation in many countries, including the UK, the Netherlands, Sweden, Norway, Switzerland, Australia and New Zealand. The survey approach is also commonly used nowadays, as it is demonstrated by recent projects in Denmark (Fosgerau, Hjorth & Lyk-Jensen, 2007) and the UK (Department of Transport, 2014). The Danish study completed in 2007 serves as a strong piece of evidence for the robustness of the methodology, as it has been altered only minimally over the course of three full-scale surveys during 20 years.

The collected data may be one of two types: revealed-preference (RP) or stated-preference (SP) surveys. The main limitation of RP surveys is that they are only usable for existing situation analysis, because of the requirement to answer questions about actual behavior. Additionally, they require a considerable amount of knowledge about the decision environment and they produce highly correlated outcomes (Fowkes & Wardman, 1988). SP type surveys, on the other hand, are capable of providing information of non-existent, hypothetical situations and are the main tool for VTT assessment. In the surveys respondents are presented with the choice of money versus time savings (Fosgerau, Hjorth & Lyk-Jensen, 2006). Respondents are asked to evaluate hypothetical choices between money and time, which can be expanded to meet the requirements of virtually any study (Antoniou, Matsoukis & Roussi, 2007; Small, 2012).

Review of international evidence from abovementioned countries and scientific studies, shows that a stated-preference survey, followed by econometric calculations is the most appropriate method of obtaining VTT for Vilnius. The authors employ the latest methodological approach while keeping the level of complexity low. In this way, the results are achieved in an efficient and accurate manner. The decisions for choosing some details of the approach are based on the review of most recent VTT studies by Fosgerau, Hjorth and Lyk-Jensen (2007), Department of Transport (2014) and Bates, Burge, Rohr and Vuk (2007).

3.6 Study Design

In line with the abovementioned academic research and national studies, the authors of this study make use of the SP surveys and later derive Vilnius-specific VTT from the obtained data. Data collection is carried out by the authors, who gather observations from respondents in Vilnius. The process is done through face-to-face interviews during respondents' actual trip with public transport. As the trip consists of walking, waiting and in-vehicle time, any of these stages are regarded suitable for conducting a short interview and are treated equally.

Usually, similar surveys are carried out in a two-step method: initial recruitment and follow-up mail surveys. This is mainly due to larger scope of the research, more financial and time resources available, and complexity of the survey itself. For the case of Vilnius, the former factors are less binding, thus, carrying out a survey during the passenger's journey is acceptable. Another factor of concern is the error rate, which can differ due to interview conditions (i.e. mail surveys present stress-free and unlimited time conditions to complete them, while there are considerable disturbances surveying respondents during their journey). This bias can be eliminated or at least minimized by adopting a method also used in previous research – introducing a control variable to check whether the respondent has understood the purpose of the survey correctly.

Any value of travel time estimations separate two types of trips: business and non-business. The former purpose for trips is usually very marginal, substituting only around five per cent of all trips. This is due to the fact that business trips should be regarded as journeys done as a part of employee's work. The method of estimating the value of time for these journeys is based on employee's wage rate and is vastly different from the one employing SP surveys. Its development is reviewed thoroughly in Bates et al. (2013). After careful considerations about the impact on the final results and a review of current Vilnius public transport statistics, the authors decide to disregard business trips from the analysis. All the upcoming analysis is limited to non-business trips (i.e. commuting, leisure).

3.7 Sample Choice

As the main purpose of the study is to estimate the time for Vilnius city inhabitants, the authors gather data for the average public transport user. However, due to the relatively small scope of the study, there is a probability of a bias. To achieve a more accurate value, authors seek to minimize error probability by the following sample choice.

The authors aim to gather around 350 responses from Vilnius public transport users. The survey sample covers different periods of the day, people with various occupation and income. Previous studies present a sample size ranging from 2,000 to 10,000, of high complexity of econometric analysis. When seeking a basic VTT estimation, a smaller sample size is a credible and acceptable choice, as shown by Bates et al., (2004), which reviews successful VTT calculations with sample sizes of 129, 400 and 500 respondents.

To observe a wide range of respondents in the sample and ensure that the value is as close as possible to the average, the surveys are conducted in specifically chosen locations. First of all, these are public transport stops, as the passengers of public transport can be easily identified. Moreover, they are not engaged in any other activity than waiting for their transport. This allows using a short period of time for the completion of the survey. The specific public transport stops are selected upon several criteria, such as their busyness during peak and non-peak hours, number of public transport lines and geographical spread. As the VTT also depends on the overall journey duration, it is more likely to gather different observations when conducting the survey in stops that are busy, geographically distant and have a high number of lines.

3.8 Questionnaire Design

Bates et al. (2007) presents a thorough analysis of the best practices for VTT study design. During pilot testing and in-depth interviews, this paper examines different methods of gathering the necessary information, best approach for questionnaire sequence and visual format. As a plethora of information on the topic is available, the authors decide not to engage in a formal pilot phase of questionnaire testing and, if necessary, make minor adjustments during the course of the survey. The questionnaire is designed in accordance to the experience from previous studies, being split into three parts in this sequence:

1) Screening questions
2) Stated-preference choice questions
3) Socio-economic characteristics

The questionnaire begins with screening questions. The main purpose of the questions is to gather information about the respondent's current (base) trip, its cost and trip purpose (business, non-business, work, studies, etc.) The first two variables also play an important role for statistical evaluation of VTT. After the second part with SP choice questions, the respondent is asked some socio-economic questions that include gender, age and occupation.

The second part of the survey contains 7 different binomial choice questions. In these questions, people are asked to make a choice between cost and time savings or losses, referencing to their current trip. There are 6 questions designated to measure the individual preferences towards exchanging money for time. There is one more additional question, which is always presenting a better alternative with both time and cost savings. This question is included to check whether the respondents have understood the survey fully.

3.9 Statistical Design

The main statistical data is collected from the stated choice experiment. The authors choose the basic model that contains only two variables – price and time. Following the methodology of Bates et al. (2007), Bradley design is used to construct the choice sets for respondents. Having inquired about the respondent's reference trip, a five step change approach allows offering alternatives to the trip. In such way, 16 different choice situations are computed, avoiding dominant choice questions. The authors choose the size of the changes for both price and time, after having reviewed research that has used similar methodology. Bradley design set is detailed in Appendix 2. As one respondent answers 6 choice questions, the full set is covered with every 3 respondents (two choice options repeat). To introduce a dominant control variable, an extra choice is added to the questionnaire, following the first six.

3.10 Econometric Approach

The statistical approach for VTT calculation has been developing for the last few decades, however, no unanimously accepted concept can be found. The discrete choice survey data is generally analyzed by logit and probit models, which in practice yield similar results. However, the specifications of these models relatively vary with every research. Most of the studies mentioned earlier employ random utility function for the calculations, with very few exceptions. Having reviewed the newest available research data, the authors choose to use multinomial logit model and random utility function. For such kind of analysis, the majority of studies for VTT use statistical software "R". This freeware software allows the user to install the necessary models for a specific statistical analysis. The regressions are carried out with a software based on the R program, however, with an advanced graphical interface, called RStudio.

a. Random utility function.

Random utility model enables the researchers to value each choice of a person. As one chooses an alternative out of the given i alternatives (in this case two), it is assumed that the choice is made for utility maximization. Utility, denoted as U_i, consists of two components, which explains the random factor. Firstly, an observed component, a function of different explanatory variables, X_i:

$$U_i = \beta_i X_i$$

The second component contains an unobserved information variable, the error term ϵ_i, which influences the choice of utility and is regarded as random during research. Therefore, choice i carries a utility level:

$$U_i = \beta_i X_i + \epsilon_i$$

Such utility level is deterministic for the choice-maker and random (as it involves a random component) from the viewpoint of the researcher. To statistically examine the choices, a model for probability analysis must be used, namely logit or probit model. The final equation used for the regression is the following:

$$U_i = \beta_1 X_i + \beta_2 Z_i + \beta_3 C_i + \varepsilon_i$$

U_i – utility of choice i

β_1, β_2 - coefficients of the observed effects variables

β_3 – coefficient of the control variable

X_i – time variable i

Z_i – price variable i

C_i – control variable i

ε_i – unobserved effects error term

b. Multinomial logit model

The general idea of the multinomial logit model used for the purpose of this research was firstly explained by McFadden (1974). Its contemporary application, specifically with the software R, is explained in detail in Croissant (n.d.) and lists three hypotheses for the error term distribution that need to be considered:

1) Independence of errors. Using univariate distribution only a one-dimensional integral is needed for the calculation of probabilities.
2) Gumbel distribution. Each error term follows a Gumbel distribution.
3) Identically distributed errors. Ensures homoscedasticity.

When the former hypotheses are realized in the model, the distribution of errors terms correspond to the observed component of the regression after a logit transformation.

c. VTT Calculation

After having carried out the regressions, VTT calculation from the results is fairly simple. The coefficients β_1, β_2 show marginal utility and cannot be interpreted straight away. However, when dividing coefficients, the result is the marginal rate of substitution. When the variables represent time and price, such marginal rate of substitution shows how much money a person is willing to exchange for a unit of time. Hence, the formula is the following:

$$VTT\ (\frac{currency\ units}{hours}) = \frac{\beta_1}{\beta_2}$$

4. Data

4.1. Survey Data

The authors have collected a sample of 350 respondents from five public transport stops in Vilnius. For the final regression, to avoid outliers, the sample was selected to include respondents who travel only to studies and work, and those who travel less than 45 minutes. The remaining part of the sample was travelling for recreational or other purposes, their trip exceeded the maximum travel duration limit set by the authors or they failed to provide a logical answer for the control binomial question. The trip duration limit was set in order to keep consistent with one stated preference choice model, as after 45 minutes, time savings of three or seven minutes become negligible. After the data selection, the sample size has been reduced to 334 respondents. As every respondent has made his or her choice six times in a row, the sample yields 2004 discrete choice answers, which ensures validity of statistical results in terms of significance, accuracy and VTT estimation. Slightly larger general purpose surveys carried out by ME "Susisiekimo paslaugos" indicate a lower range of male to female ratio and higher range of age groups. However, the survey carried out by the authors includes a fairly comprehensive sample of the average Vilnius public transport user. The data description is provided below:

- 334 respondents
- 192 males, 142 females, a ratio of 1.35 male to female
- Average age is 29.4 years, the youngest being 13, the oldest being 68
- 173 people were traveling to work, 161 to studies
- Average trip duration was 27.5 minutes; the shortest trip is 10 minutes and the longest is 45 minutes

183 people were eligible for a discount ticket, 151 paid the full price

4.2. Vilnius Public Transport Fleet

To provide a more comprehensive view on the current public transit infrastructure in Vilnius, the authors analyzed the available fleet statistics. Vilnius public transport has 95 routes, 77 of which are served by 334 buses, 6 of which are fast route buses, which are much faster and have a shorter travel time, and 18 are served by 186 trolleybuses. Consequently, 64% of all public transport users rely on bus transit and 36% on trolleybuses. The number of passengers in buses has been steadily increasing over recent years, while for trolleybuses there is an opposite trend, which was due to a reorganization of the public transit in 2012, making buses a more attractive mode of transportation as they are able to serve more areas with less investment required (as in the case for trolleybuses, additional investments are needed for the network of cables).

After the implementation of six faster routes, the distribution of passengers in public transportation has also changed, as people are willing to use the fast routes more than the usual ones, and therefore some fast routes on average have up to 35,000 passengers per day, whereas the lesser-used routes sometimes barely reach a thousand daily passengers (ME “Susisiekimo Paslaugos”, 2013).

4.3. Vilnius Public Transport Fleet

With a large fleet in place, the public authorities want to focus on increasing the utility of users. Mr. Nikitin has outlined the already existing projects in Vilnius city: 1) smart card ticketing system, with several possible ticket variations, which are slowly gaining popularity among different types of passengers, 2) real time information displays at 40 public transport stops and 3) a mobile ticket system which is currently under testing and is soon to be released (A. Nikitin, personal communication, 11 February, 2014).

The e-ticket system is functioning since 2012, in combination with the Vilnius citizen card. Instead of buying paper tickets, citizens might buy only one card and charge it with one of many possible ticket versions. Even though the possibility to buy tickets in a bus or trolleybus still remains, the city is moving to completely e-ticket system. (A. Nikitin, personal communication, 11 February, 2014)

The real time information displays at stops are empowered by GPS tracking devices installed in public transit vehicles, which record information about the location of the vehicle every 30 seconds, and deliver the information to the screens in 40 stops within the city. Users waiting at those specific stops can see the estimated arrival time of the bus or trolleybus serving their route, instead of having to rely on paper timetables hung out in the stations. The data is also transmitted online, and users can track the real time movement of public transit vehicles via Internet. However the system is not fully developed and most users rely on external platforms, such as the marsrutai.lt mobile application to plan their trips ahead (A. Nikitin, personal communication, 11 February, 2014).

The mobile ticket system is one of three Smart Vilnius projects, which are jointly funded by the Vilnius city municipality and EU. It is a mobile application, which serves as a ticket – by using a smartphone, a passenger can add credit to his mobile ticket, use it as a physical ticket, by showing the QR code to the controllers and it can be used by more than one person. This project will change the usage of public transit in Vilnius, however it will take time for public transit users to start the transition from conventional ticketing systems to a mobile ticketing system (A. Nikitin, personal communication, 11 February, 2014).

5. Empirical findings

5.1. Interview findings

a. ITS implementation

According to Paulius Keras, the director of the transport department of Kaunas city, the movement towards a smarter public transportation started in 2007 with the introduction of the e-ticket system, as well as GPS tracking technologies in public transport vehicles, which collect and send information to the transport management company as well as to the real time information system (P. Keras, personal communication, 28 January, 2014).

The system was developed with the goal to encourage citizens to buy electronic tickets. The initial reaction of the general public was rather negative, and, according to Mr. Keras, this was mostly due to the perceived complexity of the system – in a consumer satisfaction survey in 2005, 22% respondents replied that the biggest problem was the complexity in charging the ticket, whereas only 1.6% stated that there is a lack of information related to the ticketing, therefore the general public was ambiguous about the innovation. The city is now considering several potential ITS applications, including a priority system for public transport in traffic light regulated cross-sections in the city to potentially reduce errors in schedule (P. Keras, personal communication, 28 January, 2014).

Similarly to the city of Kaunas, modernization in the public transport infrastructure in Vilnius began with the implementation of the e-ticket system, which was a project jointly coordinated by representatives of the three Lithuanian cities – the third being Klaipėda. Currently, the city has several ongoing ITS related projects related to public transport, it also considers a renewal of already existing systems to improve the current travel experience – mobile applications, improved GPS tracking and real time information (P. Keras, personal communication, 28 January, 2014).

b. Transportation project evaluation

For transportation project evaluation, the city uses the conventional method of cost and benefit analysis, by considering benefits as: 1) economic value of passenger load increase, 2) income from subsidies and compensations (e.g., subsidies from EU funds) and 3) environmental impact, and weighing the benefits against the costs of the investment. According to Mr. Keras, time savings are not considered in the case of ITS project evaluation, as they are mostly used for route planning, by assuming the opportunity costs of changing a route.

In the case of real time passenger information system, the city did not conduct a specific research for the benefits, as the project was implemented as a bundle together with the e-ticket system. The potential value added from implementing ITS was neglected as it was presumed to be as an innovation that would definitely have positive value added to the citizens and have no negative aspects (P. Keras, personal communication, 28 January, 2014).

Equivalently in Vilnius, conventional evaluation methods are applied and time value analysis is not conducted when considering an ITS investment. According to Mr. Nikitin, time savings are only considered in analyzing developments in the car parking infrastructure or developing and adjusting public transport routes (A. Nikitin, personal communication, 11 February, 2014).

c. Future projects

Both cities are steadily moving forward to ITS integration in public transportation. Alongside with the plan of a fully integrated travel information system (GPS tracking in vehicles, real time information at stops, in vehicles and online) a mobile ticketing system is being developed, which will be the most innovative system in Vilnius by far, gradually eliminating the need for paper or electronic card based tickets. The application will allow additional functionality, such as the ability to purchase different ticket types, as well as to be used by multiple users at once. Alongside, Kaunas is preparing a project where 22 traffic lights in one of the busiest streets in the city will have a priority system for public transport vehicles, which will improve the reliability of routes operating in that area (P. Keras, personal communication, 28 January, 2014; A. Nikitin, personal communication, 11 February, 2014).

According to both Mr. Keras and Mr. Nikitin, the implementation process in both cities is slowed down due to the complexity of receiving EU project funding as well as inefficiencies during public procurement, especially in the case of purchasing new technology – by the time the projects are prepared, the initial technologies might have already developed and the pricing changed, therefore the cities face the problem of buying already outdated systems for a higher price than currently exists in the market (P. Keras, personal communication, 28 January, 2014; A. Nikitin, personal communication, 11 February, 2014).

Both of the cities have been working in the sphere of ITS implementation and improving the general conditions of public transit, and have a positive outlook towards further innovations. Despite the problems that occur due to the sometimes inefficient public procurement system, projects are moving forward and the motivation for further developments exists. This is partly spurred by the fact that due to the membership in the

European Union, cities are strongly encouraged to take up smart city initiatives. This is enabled by knowledge sharing among cities, which undergo similar projects or have already implemented that and can serve as a good practice example to other member states.

5.2. VTT from the Statistical Analysis

Using the multinomial logit model regression with random utility function, the authors have obtained the primary estimates of VTT. The regressions are carried out according to the chosen methodology and its assumptions. The sample size is 334 respondents, which have made a choice between money and time for six repeated occasions. The data processed by statistical software "R", results in 2004 observations for the regression. Independent variables are price and time, while final regression equation includes control variables of age, gender and trip destination. Both of the independent variables show statistical significance, while the only weakly significant control variable is occupation. The intercept is removed in accordance with the approach used by Croissant (n.d.).

Table 1. Multinomial logit model

	coeff.	t-statistic	Standard error
price	-0.382	**-2.433***	0.157
time	-2.670	**-4.313*****	0.619
gender	-0.063	-0.706	0.089
age	-0.003	-1.439	0.002
destination	-0.083	**1.744•**	0.048
Notes	Log-likelihood = -1378 •t<.1, *t<.05, **t<0.01, ***t<0.001, two-tailed		

Source: created by the authors using "R" statistical software.

For the calculation of Vilnius public transport user VTT, marginal utilities are used, which are the regression coefficients of the independent variables. Their ratio shows the time value:

$$VTT\left(\frac{LTL}{h}\right) = \frac{\beta_{time}}{\beta_{price}}$$

The obtained value indicates that the VTT estimate for Vilnius city public transport user is 2.02 EUR per hour.[1] The value is confirmed to correspond to research reviewed in the literature part, which suggests that the result should be around 50% of the average hourly wage. According to Statistics Lithuania (2013), average hourly wage in Vilnius city is 4.36 EUR. The VTT obtained by the authors accounts for 46.3% of the average hourly wage. This result justifies its use with the travel time reduction savings to estimate the benefits of certain ITS implementation in Vilnius in the cost and benefit analysis.

5.3. Cost and Benefit Analysis

During the data gathering process both from Vilnius and Kaunas municipalities and external sources (foreign municipalities, research papers, suppliers) it turned out that in most of the cases the costs information is not available for several reasons:

1) Confidentiality issues – until the project is fully completed, data is not fully processed by the municipality and therefore it is not being published.
2) Some specific ITS improvements are purchased and implemented together with several other improvements, and thus the information is readily available only for the cost of the full project.
3) ITS suppliers provide detailed costs only after having received official tenders.

Subject to limited data availability of technological costs and their time-saving benefits, the authors have selected a single ITS for which the necessary information of both costs and benefits has been available. While this factor limits the final stage of the research, it eliminates the potential ambiguity of assumptions made due to incomplete information and allows to create a framework for an ITS improvement in public transport infrastructure of Vilnius city.

5.4. Benefits

For this research, the authors chose to analyze the potential time savings impact on two routes in Vilnius city – 4G, which is a rapid bus route, and 7 (trolleybus route). These routes have the largest numbers of passengers going through them daily, weekends excluded (see Table 2).

[1] The data and regression are subject to LTL currency figures, which are recalculated to EUR using a fixed exchange rate of 3.4528 LTL per 1 EUR.

Table 2. Top five bus and trolleybus routes

Route	Daily passenger estimates
Buses	
4G	**31,293**
3G	25,833
2G	25,420
1G	23,279
5G	24,236
Trolleybuses	
T7	**30,097**
T2	21,392
T16	20,355
T19	20,099
T17	16,784

Source: created by the authors using ME "Susisiekimo paslaugos" data.

The authors will analyze the potential time saving implication of the Split Cycle Offset Optimization Technique (hereafter, SCOOT), which is a bus priority at traffic lights system used in many cities worldwide with measured time saving results at junctions (Bretherton et al., 2009). According to the providers of the system, after implementation it is possible to save up to 5 seconds per junction (2-4 seconds being the average possible time savings per junction). Nonetheless, by providing extra priority for public transport at certain stages, it reduces the timing that is reserved for the intersecting stage, resulting in minimal time losses to other participants in the traffic (Bretherton et al., 2009).

The number of traffic light regulated intersections for the route 4G and route 7 are, respectively, 31 and 26, with two intersections covered by both the routes, which implies less costs for implementation and maintenance (A. Nikitin, personal communication, 11 February, 2014).

Currently the municipal transportation of Vilnius does not have a developed passenger tracking system, as the current smart ticket requires it to be checked in only once per month, and thus it is impossible to have precise amounts of passengers going in and out of a vehicle. However, the municipality has undertaken research to estimate the total number of passengers that use each of the routes that the city provides.

Estimates provided by municipality do not take into account the time that a passenger spends in the vehicle. Therefore, the estimation of passengers will be based on using the Passenger Load Factor (hereafter, PLF). The PLF is a measure which allows determining the average load of a vehicle, by dividing the available seat kilometers by the actual seat kilometers. Essentially, multiplying the PLF with the maximum capacity of a public transit vehicle will provide an estimate for the average number of passengers on a specific route at a specific time.

$$PLF = \frac{Actual\ Seat\ Kilometers}{Available\ Seat\ Kilometers}$$

The measure Actual Seat Kilometers is calculated by multiplying the following variables:

- No. of buses serving the route
- No. of times a vehicle completes the route
- Length of route (km)
- Maximum capacity of a vehicle (sitting and standing)

The actual seat kilometers for both the chosen routes were provided by ME "Susisiekimo Paslaugos". After the calculations, the estimated value of the PLF is 12.33% for route 4G and 19.06% for the trolleybus route 7. The estimation of passengers potentially affected by the implementation of ITS is therefore:

$$Passengers\ affected = PLF \times Max.Capacity \times No.of\ vehicles \times No.of\ trips$$

By multiplying the maximum capacity of a vehicle with the PLF the authors obtain the average number of passengers per vehicle. By multiplying with the amount of vehicles and the times they complete the route, the estimated total number of passengers per day is consequently acquired (see Table 3).

Table 3. Passenger estimation.

Route	PLF	Max. Capacity	No. of vehicles	No. of times	Total
4G	12.33%	90	26	12	3,461
T7	16.37%	83	35	10	4,756

Source: created by the authors using ME "Susisiekimo paslaugos"data and authors' calculations.

As a result, the 4G bus route, which passes through 31 traffic light controlled intersection is able to, all other things held constant, potentially save 214,636 seconds per working day, and the trolleybus route 7 with 26 intersection can save 178,262 seconds per working day (see Table 4).

Table 4. Estimation of present value of time savings.

Route	Daily time savings (hours)	Annual time savings (hours)	time savings (EUR)	10 year PV (EUR)
4G	59.62	15,024.59	30,349.67	223,376.2
T7	81.91	20,640.58	41,693.96	306,871.19
Total PV, EUR				**530,247.39**

Notes

1) The value of travel time is 2.02 EUR/hour
2) The benefits are discounted at a fixed 6% rate annually due to general recommendations by the European Commission regarding project evaluation (European Commission, 2008)
3) As the analysis is based on working days, the assumed working days per year is 252
4) A 10 year period is standard for evaluating transportation projects **(**P. Keras, personal communication, 28 January, 2014)

Source: created by the authors.

The estimated travel time savings are therefore 530,247.39 EUR. These are the total benefits in this analysis. This is the benefits for the two routes only. However, the estimation has several important assumptions:

1) Ridership increases held constant; the estimation hold ridership rates in the upcoming 10 years to be constant.
2) Routes remain constant: both the routes are to remain constant – no adjustments to number of stations or crossings in the existing routes.
3) Value of travel time remains constant: the estimated value of travel time is assumed to remain constant in the period of 10 years.
4) Inflation and other economic factors are held constant and not included.

5.4. Costs

The costs associated with installing SCOOT technology into Vilnius public transport infrastructure can be classified into implementation and maintenance costs. Following the CBA guidelines provided by Transportation Economics Committee (n.d.), various cost subcategories are taken into account and yearly maintenance costs are assumed to be 8% of the total technology cost, followed by 10% annually after the 5^{th} year. As suggested, depreciation costs are not taken into account and currency values are constant. SCOOT technology requires expenditure for three transport infrastructure areas: intersections featuring traffic lights, public transport vehicles and traffic management system. As the CBA is limited to a specific technology and its effect, the cost figures represent investment and present value of maintenance for the selected public transport routes and vehicles operating in those routes. Pre-existing resources available at the disposal of ME "Susisiekimo paslaugos" are considered, however, for the purpose of the CBA, are not accounted for. The summary of cost information is presented below in Table 5, while detailed cost information can be found in Appendix 3.

Table 5. Summary of present value of costs

	% of total	Total, EUR
Intersections with traffic lights	84.38%	412,559.40
Public transport vehicles	4.59%	22,476.39
Traffic management system	11.01%	53,843.36
Total PV, EUR		**488,879.15**

Notes
1) Technology for intersections with traffic lights includes full SCOOT modules to be installed in existing traffic lights
2) Technology for vehicles includes SCOOT-compatible GPS trackers
3) Traffic management system includes both hardware and software
4) All cost figures include initial investment and PV of maintenance for 10 year period
5) The costs are discounted at a fixed 6% rate annually due to general recommendations by the European Commission regarding project evaluation (European Commission, 2008)

Source: created by the authors using ME "Susisiekimo paslaugos" data.

The final costs figure amounts to 488,879.15 EUR. Such investment allows Vilnius public transport company to install SCOOT system on 55 intersections in the city, which are situated on the routes of two of the busiest public transport lines. Additionally, 26 buses and 35 trolleybuses would be equipped with GPS tracking systems. The sum includes deployment and maintenance costs for 10 years of the system's lifespan. This is the final figure to be used for CBA ratio calculation.

6. Discussion of Results

The final result of cost and benefit analysis implies a positive ratio of 1.09, which can be regarded as moderate. This means that if Vilnius city decides to invest in the proposed ITS technology in its public transport, the monetary benefits of value of travel time savings would exceed the required financial expenditure during a period of 10 years. In transportation project appraisal, a benefit to cost ratio higher than 1 suggests approval of the project.[2] The empirical findings of this study almost unambiguously suggest that traffic light priority system for Vilnius public transport is beneficial and should be implemented. The CBA model, where benefits stem entirely from time savings, is widely used in foreign countries to assess transportation project (Bates et al., 2004). Nevertheless, such projects are one of the most complex and wide-scoped operations in their nature: due to the high variety of areas that have to be considered, basing an investment decision on a single-sided measure can be controversial. Hence, the approach used by the authors must be critically examined, to evaluate the possibility of shortcomings in the assumptions made, which should be treated with caution for policy makers.

6.1. Value of Travel Time Estimation

They key variable in the authors' study is considered to be the value of travel time, which is the basis for monetary benefits of CBA. The authors have successfully estimated the value to be 2.02 EUR per hour of travel time saved for a Vilnius public transport user, which can be confirmed when comparing it to the average hourly wage. Estimated VTT in this paper serves as an approximation of the true value due to:

1) Limited sample size
2) Surveys carried out during working days
3) Surveys carried out only in most popular public transport stops
4) Only two main destinations of public transport passengers
5) Equal treatment of big and small travel savings

These arguments imply that the value can deviate from the true average value to a certain extent. However, the authors believe that the even a simplistic method of estimating VTT is suitable for the needs of this research and serves its purpose accordingly – to create a precedent transport project appraisal framework for the city of Vilnius. With more funding,

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[2] The statement is only valid when there are no other projects considered with a higher CBA ratio.

the VTT estimation can be refined, by estimating a more precise average public transport value and expanding the scope and estimating different values to fit the peculiarities of the transportation project in question.

6.2. Costs and Benefits

The cost analysis presented covers both of the necessary parts of the total expenditure for an ITS improvement – initial investment and maintenance. The authors have analyzed a single technology subject to data availability. The projected costs can be considered to be rather theoretical and may differ in practice. To reduce this uncertainty, practical guidance from ME "Susisiekimo paslaugos" was sought and the cost figures were adjusted accordingly. As it turned out, transport improvements are rarely considered only in terms of specific technologies and in most cases transport projects are executed on a larger scale; authors do not account for the effects that may reduce or increase the expenditure when assessing a set of technologies. Also, as only base costs were considered and existing resources were not included in the calculations, actual figures may differ. However, the costs considered in the CBA fully correspond to the effects that those technologies would have and are comparable. While limited, the cost estimation not only creates a feasible framework, but also allows the authors to answer the research question and provide guidance for further research.

The benefits estimated employing VTT are substantially higher than the calculated expenditure and imply that the whole project would be beneficial for Vilnius public transport. As additional measures (i.e., passenger load factor) were undertaken to estimate the number of people affected by the ITS improvements, a possible deviation from the true value is possible. Having allocated the necessary resources, such issue could be solved by collecting specialized data, which is not available at the moment of the research. Moreover, the benefits are highly dependent on the correct value of VTT, which should be of the highest priority when assessing a project. When VTT is estimated accurately, calculation of the benefits does not impose considerable difficulties.

6.3. Overall Outcome

Having considered the plausibility of assumptions made, the authors conclude that the purpose of the study has been achieved and results can be confirmed. The empirical findings suggest that the research question is answered and ITS improvements can economically benefit Vilnius public transport system. A practical framework has been created for transportation project appraisal in terms of ITS in Vilnius city and can be adapted for further research needs.

6. Conclusions

Transportation improvements have long been of core importance in agendas of many municipalities. The complexity of the whole urban transport infrastructure makes investments in transport projects very complex and multifaceted, as several stakeholders are involved in every project, and the impacts are very wide, ranging from environmental benefits from reduced emissions, congestion or time savings from faster routes.

This study aimed to analyze whether the implementation of a specific ITS into the public transport infrastructure in the capital city of Lithuania, Vilnius, is economically beneficial. After an overview of a few ITS options, public transport priority systems at traffic lights were chosen as a subject of analysis, because they generate time savings for the passengers and have a clear implementation strategy. The authors interviewed representatives of transport management departments in the two largest Lithuanian cities, Vilnius and Kaunas, in order to understand what kind of progress has been made in terms of ITS and also to enquire about general transport project evaluation. Both cities have already made significant progress in adapting ITS, especially Vilnius, which already has a smart ticketing system, real time passenger information system and also is about to release mobile applications which leads to more efficient travelling. The city does not have precise ITS plans for the future, but has a positive outlook to further developments. Transportation project evaluation does not have any specific guidelines in the city, and travel time savings are not considered when evaluating investments.

An empirical design was therefore established for evaluating the average VTT in Vilnius, which was later on used in the cost and benefit analysis to obtain a ratio which determines whether the investment is beneficial to the city and its citizens. The estimated benefits outweigh the costs of the investment and therefore deem the investment beneficial.

The study provides a basic approach for evaluating transport projects by estimating the VTT measure for an average public transport user and therefore monetizing the time savings that are achieved by an investment in the infrastructure. However, this approach has to be expanded even further, as the estimation of VTT was basic, therefore a larger scale survey should be carried out to obtain more precise results. Furthermore, the current statistics of passengers affected could be improved by a more developed system for estimating passengers, as current figures are based on several assumptions, which could skew the statistics. However, such an approach would require a separate monetary investment solely for the purpose of surveying.

Future studies in the field could consider improving the VTT estimate by increasing the sample size. Additionally, other time saving technologies could be analyzed by applying a similar cost and benefit valuation model, or a more expanded priority system could be evaluated, covering more than two routes in the city. The authors believe that further research could be carried out to find an optimal number of priority systems to be used in the city.

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Appendix 1. Summary of researches linking VTT to hourly wage rate.

Table 1. Previous researches confirming relationship between VTT and hourly wage rate

VTT as % of average wage	**Year**	**Author/organization**
25-50%	2008	Litman
25-35%	2013	Victoria Transport Policy Institute
31-50%	1965	Beesley
40%	1965	Becker
42%	1992	Waters
42%	2001	Boiteux & Baumstark
50%	2003	U.S. Department of Transportation
50%	2005	Boardman et al.
50%	2009	Concas & Kolpakov
72%	2001	Small & Yan

Source: created by the authors.

Appendix 2. Questionnaire choice sets

According to Bates et al. (2007) the best approach when there are two variables is to create a 16 variations choice set to fully cover all possible options. Every survey participant is asked to make 6 choices between money and time, which implies that the two choice pairs have to be repeated, making the final choice set to be in the form of 16+2. All values imply changes to the respondent's base trip and base cost for it. After reviewing statistical design examples, the time and price changes have been arbitrarily adapted to suit Vilnius public transport. Survey respondent randomly received one out of three choice set's sub-set.

Table 1. Adapted version of Bradley design for stated preference choices

Sub-set	**Pair no**	**TimeA**	**PriceA**	**TimeB**	**PriceB**
1	1	0	0	-3min	+50ct
1	2	+7min	-20ct	0	0
1	3	-3min	+20ct	0	0
1	4	+7min	0	0	+20ct
1	5	-3min	0	0	-20ct
1	6	0	-50ct	-3min	0
2	1	+3min	0	0	+50ct
2	2	0	+20ct	+3min	0
2	3	0	-20ct	-7min	0
2	4	0	0	-7min	+20ct
2	5	-	+50ct	+7min	0
2	6	0	0	+3min	-20ct
3	1	0	-20ct	-7min	0
3	2	+3min	-50ct	0	0
3	3	-7min	0	0	-50ct
3	4	-7min	+50ct	0	0
3	5	0	0	+7min	-50ct
3	6	0	0	-20ct	+50ct

Source: created by the authors according to Bates (2007).

Appendix 3. Cost Breakdown.

Table 3.1 Costs associated with intersections on routes.

	Quantity	**Price, EUR**	**Total, EUR**
SCOOT module per intersection (route 4G)	31	4,439	137,609
SCOOT module per intersection (route 7)	24	4,439	106,546
Deployment per intersection for both routes	55	100	5,500
PV of unplanned expenses for year 1 maintenance	1	4,000	3,773.58
PV of maintenance for years 1-5	8% of technology cost*5	19,532.4	82,277.57
PV of maintenance for years 5-10	10% of technology cost*5	24,415.5	76,853.23
Total PV, EUR			**412,559.38**
Notes	1) ME “Susisiekimo paslaugos” suggests the addition of unplanned expenses and increase in maintenance for years 5 to 10 2) SCOOT modules include loop detectors, automatic vehicle identification system, hardware for traffic lights 3) The costs are discounted at a fixed 6% rate annually due to general recommendations by the European Commission regarding project evaluation (European Commission, 2008)		

Source: calculations made by the authors using ME “Susisiekimo paslaugos” data.

Table 3.2. Costs associated with vehicles

	Quantity	**Price, EUR**	**Total, EUR**
GPS module per vehicle (route 4G)	26	170	4,420
GPS module per vehicle (route 7)	35	170	5,950
Deployment per vehicle for both routes	61	30	1,830
PV of unplanned expenses for year 1 maintenance	1	1,000	943.39
PV of maintenance for years 1-5	8% of technology cost*5	829.6	4,148
PV of maintenance for years 5-10	10% of technology cost*10	1037	5185
Total, EUR			**22,476.39**
Notes	1) ME “Susisiekimo paslaugos” suggests the addition of unplanned expenses and increase in maintenance for years 5 to 10 2) Location tracking modules are already installed on Vilnius public transport vehicles, however, not compatible with SCOOT system 3) It is assumed that the same vehicles will continue serving the selected routes 4) The costs are discounted at a fixed 6% rate annually due to general recommendations by the European Commission regarding project evaluation (European Commission, 2008)		

Source: calculations made by the authors using ME “Susisiekimo paslaugos” data.

Table 3.3 Costs associated with traffic management system

	Quantity	**Price, EUR**	**Total, EUR**
Hardware	1	4,700	4,700
PV of software, per annum	10	3,000	23,405.08
Deployment	1	350	350
Calibration with existing system	1 FTE for 1st month	1,100	1,100
PV of maintenance for years 1-10	0.25 FTE per annum, 10 years	3,300	24,288.29
Total, EUR			**53,843.37**
Notes	1) Most of the necessary hardware would be available at the disposal of ME "Susisiekimo paslaugos" 2) Calibration is approximated taking 1 FTE of an IT specialist in ME "Susisiekimo paslaugos" 3) Maintenance is approximated taking 0.25 FTE of an IT specialist in ME "Susisiekimo paslaugos" 4) The costs are discounted at a fixed 6% rate annually due to general recommendations by the European Commission regarding project evaluation (European Commission, 2008)		

Source: calculations made by the authors using ME "Susisiekimo paslaugos" data.