DEVELOPMENT OF INTELLIGENT TRANSPORTATION SYSTEM IMPLEMENTATION IMPACT EVALUATION METHODOLOGY: CASE-STUDY OF RIGA

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ABSTRACT

The goal of current paper is to present the results of development of Intelligent Transportation Systems (ITS) implementation impact evaluation methodology, which is based on applying traffic flow simulation approach. The proposed methodology allows to solve vivid problem of making more reliable decisions on introducing ITS solutions into transport system. The proposed methodology was approbated based on Riga (capital of Latvia) case study. The results obtained during approbation allow to conclude that methodology could be used in in real projects related with integrating of new technologies into transport system by decision makers.

Keywords: sustainable development, transport system, simulation model, impact evaluation

1. INTRODUCTION

According to the definition of sustainable development, following general definition could be provided "Sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs". The definition underlines that development of the sustainable system is a complex problem which involves many internal and external factors.

For many countries (including Latvia) transport is a key element of the national economics that is why European Commission puts a lot of attention on development of sustainable transport systems. According to document published by European Commission (EC 2011) a modern transport system must meet following 3 requirements: ecological requirements; safety and effectiveness. The report of United Nations department of Economic and Social Affairs (Bongardt et al. 2011) declare that more sustainable transportation system is the system that: 1) allows the basic access and development needs of people to be met safely and promotes equity within and between successive generations; 2) if affordable within the limits imposed by internalization of external costs, operates fairy and efficiently, and fosters a balanced regional development; 3) limits emissions of air pollution and GHGs as well as waste and minimizes the impact on the use of land and the generation of noise (Bongardt et al. 2011). In general all 3 points are reference on social, economic and environmental aspects of transport.

All aspects are important and that is why in order to develop a sustainable transport system a balance between them should be found. A number of sustainable transport system development tools could be mentioned here: use of Intelligent Transportation Systems (ITS); use of P&R (Park and Ride); optimization of existing transport infrastructure; development of intermodality; implementation of new transport infrastructure elements base on strict analysis of development consequences; use of sound tax policy, use of modern technologies; application of more environment friendly technologies etc. The range of tools is wide and varies from political issues (T-TRANS 2013a) to issues related with commercialization of innovative technologies for transport sector (T-TRANS 2013b).

The most perspective and supported by European Commission issue is related with implementation of ITS. According to the definition (Miles and Chen 2004) Intelligent Transport System is integrated application of communications, control and information processing technologies to the transportation system.

ITS development process often faces difficulties. Character of these problems may be financial, technical or political. Nowadays more and more cities are trying to divide risks and financial obligations among government, local administration and stakeholders who are interested in this process. ITS requires large investments in infrastructure, hardware and software and involving the use of fast developing technologies..

Successful ITS deployment requires systematic approach. And in this aspect Public Authorities can create framework according to the national strategy of development, urban planning and according individual ITS applications.

According to the Handbook of ITS there are four key simple rules that can influence on successful project implementation (Miles and Chen 2004):

- ITS should be incorporated into the mainstream transportation planning and investment cycle;
- Use innovative procurement methods in the public sector, involving multiple evaluation criteria to secure best value;
- Project finance needs to be on a whole-life basis, including maintenance and operational costs as well as capital for start-up investment;

- Where appropriate, the private sector can be involved in partnerships and out-sourcing, both for the investment in ITS infrastructure and for ITS operations and delivery of ITS services.

As it was mentioned previously, before starting ITS development process it is necessary to understand regional transportation needs that covers all issues of sustainable development. And when key actors are identified and all priorities and requirements are stated the documentation for the project implementation could be prepared.

The basic cycle for ITS development could be presented in figure 1.

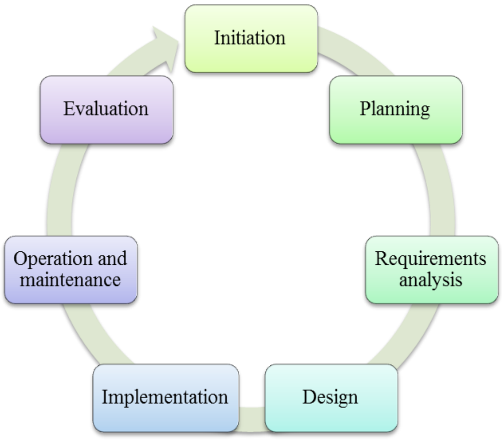

Figure1. ITS Development Cycle

The narrow step in ITS development cycle is an evaluation of the impact on social, economic and environmental issues. As could be seen from figure 1, the usual case is when we do evaluation after implementation. The main problem here is related with post evaluation of the ITS impact. That is why the presented ITS development life cycle must be upgraded with pre-evaluation phase (ex-ante assessment).

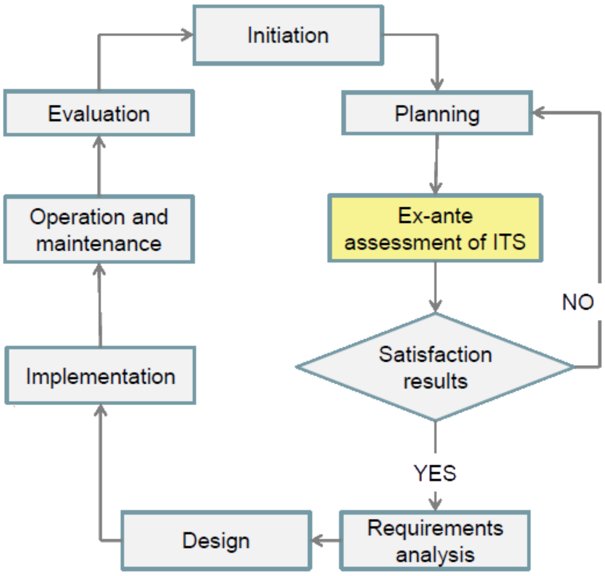

Figure 2: ITS Development Cycle Extended With Ex-ante Assessment

Introduction of ex-ante assessment in ITS development life-cycle allows to support decision makers by quantitative information about impact of the proposed solution (more to say in monetary equivalent). The next chapter is dedicated to the development of the evaluation methodology (ex-ante assessment).

2. DEVELOPMENT OF THE EVALUATION METHODOLOGY

2.1. Review of ITS assessment methodologies

It is obviously, that nowadays when transportation plays one of the leading roles in human life is presented broad and impressive list of different approaches in transportation projects assessment. In transportation field the bulk of assessments appear because of the lack of information for taking reasonable, adequate and suspended decisions. ITS as one of representatives of transportation field projects as well can be assessed using different methods. There are several directions of ITS evaluation: impact assessment, technical assessment, socio-economical evaluation, users acceptance evaluation, financial assessment and market assessment.

During technical assessment we can evaluate system performance and reliability. Technical assessment is realized with different methods, such as: field observation, field trials, pilot tests and other. Impact assessment includes evaluation of safety, transport efficiency, user behavior, modal split etc. Impact assessment as well as technical assessment can be carried out using different methods like before-after observations, field trials and pilot tests, modelling and simulation. User acceptance evaluates users' opinions, their preferences and willingness. Basic methods that are used for this evaluation includes surveys, interviews, questionnaires. After users acceptance evaluation we can distinguish socio-economic evaluation. Socio-economic evaluation allows understanding benefits and costs of system implementation. In the core of this evaluation are laying two basic methods: cost-benefit analysis and multi-criteria analysis. This two methods are quite popular in transportation assessment and will be discussed deeply bellow. Other two assessment approaches are financial assessment and market assessment. Market assessment allows understanding demand and supply, and financial assessment, using different business models, considering investment and risks can evaluate initial and return costs, rate of return, payback period and other essential economic indicators.

Each project has its own characteristics, features and limitations. The use all approaches at once is not necessary to evaluate a project. Selection of few of them which can help to assess exactly what is important to achieve the objectives for which the project was developed. Choosing correct method for evaluation is the first and significant moment for future results of evaluation. Onwards are presented two methods of evaluation that indeed become very popular in transportation projects assessment. Both methods are referred to socio-economic evaluation. Using these methods we can not only evaluate project but as well compare different alternatives in the project.

2.1.1. Cost- Benefit Analysis (CBA)

Cost-Benefit Analysis (CBA) is one of the most popular methods for transportation project evaluation. In 1960 it was first time introduced in transport project in UK. This method involves comparing the total expected cost of each option against the total expected benefits. This is done to see whether the benefits outweigh the costs, and by how much. By decision makers CBA is used for two main purposes: first, is to gain knowledge about return of investment and the second, to provide a basis for comparing projects. In CBA costs and benefits are presented in money terms. Usually this is a complex problem, but CBA use the time value of money in order to do recalculation. So, all flows of benefits and flows of project costs over time, which tend to occur at different points in time, are expressed on a common basis in terms of their net present value (NPV).

For each alternative, a single aggregate measure of economic worth is formed by adding the different impacts, considering benefits as positive and costs as negative, and taking account of the time when these occur. The definition and quantification of benefits and costs depend on the stakeholders for whom the analysis is performed. The alternative with the highest worth is preferred.

The bellow variables are present in CBA and are usually evaluated using market prices, when available (Cascetta 2009):

- **CC** Difference between the construction costs of the project and the costs of construction and other major works (reconstruction, rehabilitation), if any, required for the nonproject alternative.
- **CVT** Difference between investment costs in vehicles and technologies for the project and nonproject situations.
- **CMO** Difference between maintenance and operating costs for the project and nonproject situations.
- **REV** Difference between direct (sale of transportation services) and indirect (commercial activities) revenues in the project and nonproject situations.
- **TR** Difference between government revenues from taxes and duties in the project and non-project situations.
- **DS** Change in transportation system user perceived surplus in the project and nonproject situations, expressed in monetary units. This is typically obtained by adding up the changes in perceived surplus for different user classes
- **UNPB** Change in benefits not perceived by the users between the project and nonproject situations. These benefits might include costs changes due to accidents or vehicle operations (lubricants, tires, etc.). And other non out-ofpocket costs not perceived by the users in their travel-related choices. All these benefits are expressed in monetary units; the variable has a positive sign if there is a reduction in these costs.
- **NUI** Change in the nonuser impacts between the project and nonproject situations. Impacts on the environment (e.g., reduction of pollutant emissions) and on the economy and land use system can be included in this variable after conversion to monetary units. These impacts are sometimes referred to as indirect benefits and are positive if the benefits increase.

It is important to stress that the variables considered and the way they are computed both depend on the viewpoint from which CBA analysis is performed. The evaluation must avoid double counting of an individual project effect by quantifying its impacts with different variables having the same sign (Cascetta 2009).

Several synthetic indicators have been proposed for comparing the time streams of benefits and costs of different projects. The Net Present Value (NPV) is the equivalent value in year 0 of the time stream of annual project costs and benefits. NPV can be calculated using variables described above.

$$NPV_i(r) = \sum_{t=1}^{T} \left(\frac{DS_i^{(t)} + UNPB_i^{(t)} + NUI_i^{(t)} + TR_i^{(t)} + REV_i^{(t)} + CC_i^{(t)} + CVT_i^{(t)} + CMO_i^{(t)}}{(1+r)^t} \right),$$

where:

T – is the number of years included in the time stream;

r – is the applicable discount rate per year.

The Internal Return Rate (IRR) is defined as the value of the discount rate, such that the NPV calculated over a period of *T* years.

2.1.2. Multi-Criteria Analysis (MCA)

Usually in transportation projects decision maker have a lot of goals, and system or application may produce a variety of impact types. Often, goals conflict with each other, for example the maximization of users' surplus might conflict with the reduction of noise and air pollution. That is why good decisions need clear objectives. These objectives should be specific, measurable, agreed, realistic, and time-dependent.

MCA can help to decision makers to answer questions about project impact on different objectives. It is undertaken to make a comparative assessment between projects or heterogeneous measures. In a MCA one does not try to express all effects in one dimension – money. But several dimensions are used at the same time (monetary units, minutes, grams etc.). The overall assessment of a project or the ranking of different projects, using all the criteria, takes place by using criterion weights. MCA establishes preferences between options by reference to an explicit set of objectives that have been identified, and for which performance

indicators (that measure the degree to which an objective is attained) have been defined.
To compare the contribution of different options towards given objectives, it is necessary to have criteria that reflect the options' performance in meeting those objectives. In simple situations, the process of identifying and assessing objectives and criteria may alone provide enough information for decision-makers. However, where a level of detail broadly akin to cost-benefit analysis is required, MCA offers a number of ways of aggregating the data on individual criteria to provide indicators of the overall performance of each available option (Communities and local Government 2009).
A key feature of MCA is its emphasis on the judgment of the decision-making team in establishing objectives and criteria, in estimating relative importance weights, and, to some extent, in judging the contribution of each option towards each evaluation criterion. Its foundation, in principle, is the decision maker's own choice of objectives, criteria, weights, and her assessments of the options' performance towards achieving the objectives, although "engineering" data such as times and costs can of course also be incorporated in this process. MCA can bring a degree of structure, analysis, and openness to classes of decisions that lie beyond the practical reach of cost-benefit analysis. In general, a MCA consists of the following main steps presented on the figure 3:

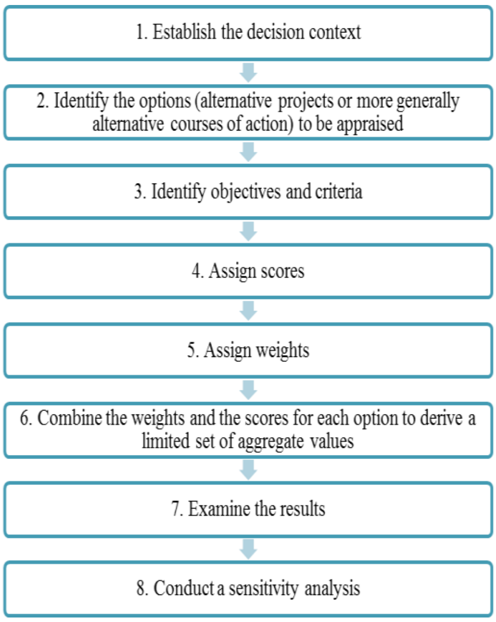

Figure 3. Steps in MCA

In the evaluation field, multi-criteria analysis is usually used as an ex-ante evaluation tool. MCA is particularly used for the examination of the intervention's strategic choices. In ex-post evaluations, multi-criteria analysis can contribute to the evaluation of a programme or a policy through the appraisal of its impacts with regards to several criteria (EU 2014).
In ex-ante or intermediary evaluations MCA can be useful (EU 2014):

- To evaluate the ability of various activities of a programme to fulfil a given objective. This assessment can take place to collect the opinions of decision-makers and beneficiaries about the effectiveness of the activities.
- To structure the views of project or programme managers about on-going activities.
- To discuss the content of the programmes, and the funding of various activities during the drafting of strategies and programmes.

In ex-post evaluations, in beneficiary countries, interventions in fields such as poverty alleviation, maintaining security, immigration control, or trade development can benefit from this type of analysis which formulates judgements on these complex strategies.

2.2. Methodology of ITS implementation impact assessment for Riga

In this subchapter the methodology for ITS impact assessment before the implementation of the real system is proposed.
This methodology can be used as a supporting tool for decision makers and transportation professionals. The methodology is proposed to help to decision maker understand the influence of proposed ITS application before it was implemented in the real transport system.
The methodology is divided into three main parts:

1. Preliminary part (analysis of the transport system for further improvement);
2. Tactical part (conceptual solution identification, impact and measures identification0
3. Main part (assessment based on the simulation).

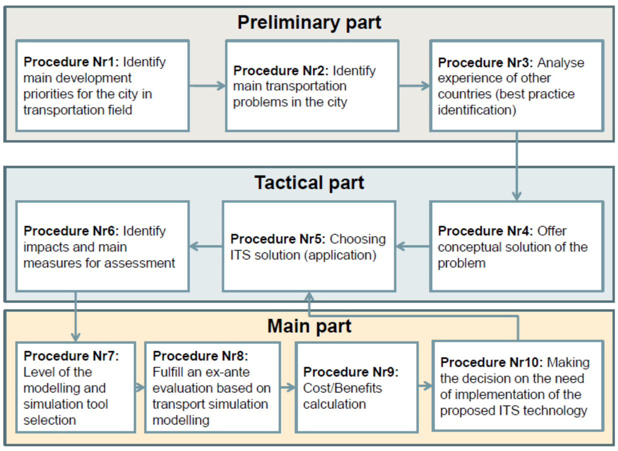

Figure 4: Ex-ante Assessment Methodology

Preliminary part consists from the steps that should be done before real assessment process, like analysis of the transportation system development priorities and problems. On the tactical part should be done the decisions which cover: conceptual solution how the problems can be solved and what technology to choose, as well impact and measures should be identified. Main part of the methodology consists of evaluation steps based on simulation and it gives the understanding of the modelling application for ITS impact assessment. If we distinguish main milestones (Figure 4) the methodology will have 3 steps in the first and in the second part and 4 steps in the main part ending with decision about proposed ITS technology.

Procedure 1: Identify main development priorities for the city in transportation field

The procedure is targeted on clearing the strategic and operational goals of TS development. This could be done by completing following:

- Analysis of different policy documentation. First of all, the documentation of the development of the city as a unified system and particularly transportation system development.
- Defining the main priorities and future trends of transportation technology, infrastructure and fleet should be taking into account.
- Defining strategic and operational goals. For that two different time periods: strategic (3- 5 years) and operational (1-3 years). Usually, short-term and long-term development priorities have one common trend. That leads the situation when long-term goal combines different short-term goals.
- When all priorities of the city transport system development are identified it should be distinguished measures to evaluate where and for how much we deviate from the priorities.

Procedure 2: Identify main transportation problems in the city

The procedure includes following sub-steps:

- Review of transportation statistics and main indicators of the goals conformity assessment. Characteristics like crashes and injuries, traffic jams and air pollution should be analysed.
- Identify the problems based on the analyses in the previous step.
- Propose different solutions for these problems. When problems were identified different solutions of how to eliminate them should be considered. These solutions may be connected with political decision or exactly with transport infrastructure or fleet. For example, if the problem is congestions in the city center political decision can be – paid entrance to the city. If the problem is dissatisfaction among users about public transport frequency, the solution may be – increase in public transport frequency by increase in rolling stock.

Procedure 3: Analyse experience of other countries (best practice identification)

The procedure 3 is targeted on following sub-steps:

- Analysis of ITS implementation process.
- Analysis of legislation aspects.
- Analysis of architecture solutions.
- Analysis of user needs.

At this procedure the goal for future improvement of transportation system experience of different countries should be analysed. Different approaches in ITS should be discovered. In ITS implementation basic parts like legislation, architecture and user needs should be analysed. Also procedure covers review of different technologies of ITS.

Procedure 4: Offer conceptual solution of the problem

The conceptual solution should be done together with transportation professionals due to this decision should be comprehensive accordingly to the priorities and be a best solution for the proposed problem.

Procedure 5: Choosing ITS solution (application)

The procedure is targeted on proposal different ITS solutions, which are able to solve existing problem. The list could be generated based on analysis of experience of other country or based on own experience.

Procedure 6: Identify impact and main measures for assessment

This procedure is targeted on identifying measures which will be used further. The measures range should be wide in order to cover three types of benefits: 1) economic; 2) social; 3) environmental.

Procedure 7: Level of the modelling and simulation tool selection

At this step the level of modelling (macroscopic, microscopic, mesoscopic) should be identified and the tool (software application) should be selected based on the future results and goal that was set before analysis. As well tool selection depends on the resources that are available at the moment. Price and functionality is the key factors in selection.

Procedure 8: Fulfil an ex-ante evaluation based on transport simulation modelling

The procedure defines of how simulation model is used within frame of the assessment methodology. The steps of simulation model application are described in figure 5. Main steps are:

- Development of a model with the baseline scenario "as is"
- Identification of measures that can be gained using results of simulation
- Preparation of the model for the experiment "as is"
- Experiment realization and necessary data collection.
- Measures assessment (experiment “as is”).
- Transport model implementation with the proposed ITS technology.
- Preparation of the model for the experiment with implemented ITS technology into the model.
- Experiment realization and necessary data collection.
- Measures assessment (experiment with implemented ITS technology).

- Results comparison before and after ITS technology implementation (benefits calculation).

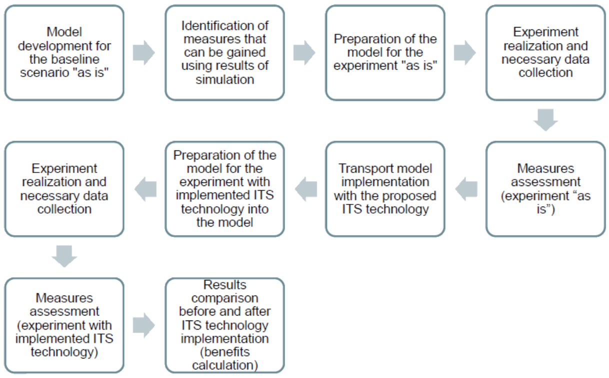

Figure 5: Evaluation Based on Transport Modelling

Procedure 9: Benefits calculation

Benefits that bring implementation of new solution should be calculated. After benefits are estimated the last step of the methodology – decision of the need of new transportation solution comes. Besides this part it is important to know not only benefits, but as well the cost of implemented application. In this work cost question is put off, but in the methodology it is distinguished as one separate step.

Procedure 10: Making the decision on the need of implementation of the proposed ITS technology

This decision should take into account the whole methodology and be comprehensive during before and after benefits comparison.

3. APPROBATION OF THE EVALUATION METHODOLOGY

The proposed methodology was approbated on Riga city. The approbation results are described in brief, to give the general view of how developed methodology is applied.

Procedure 1:

In this procedure the analysis of strategic documents for Riga city was completed. The main finding (priorities) are presented below.

The National Development Plan of Riga 2007 – 2013:

- ecology,
- accessibility,
- safety,
- efficiency.

Long-term Development Strategy of Riga until year 2025 (RDPAD 2005):

- mobility,
- reliability,
- public transport.

Procedure 2:

Analysis of statistical data about transport system of Riga gives following vivid problems:

- congestions,
- large number of traffic accidents,
- increased environmental pollution.

Procedure 3:

The analysis of European and United States experience in overcoming of mentioned above problems was analysed (study of scientific publications, books, white paper etc).

Procedure 4:

Based on previous procedures results, it could be confirmed, that in this case the ITS application could be a possible solution.

Procedure 5:

Moreover it is proposed to apply a green wave approach for traffic signals deployment as an ITS solution.

Procedure 6:

Following performance criteria and measures are used:

Performance criteria:

- mobility,
- efficiency.

Measures:

- average speed by mode,
- average speed for selected Origin-Destination,
- average delay by mode,
- total delay by mode,
- total travel time by mode,
- average travel time for selected Origin-Destination,
- network total average delay.

Procedure 7:

Microscopic simulation model of Riga transport network fragment developed in frame of project focused on pedestrian and transport flow analysis (TTI 2011). The models developed using PTV VISION VISSIM simulation software.

Procedure 8:

This step defines of how simulation model is used within frame of the assessment methodology. The steps of simulation model use are described in figure 5.

Procedure 9:

Table 1: Cost/Benefits Calculation

Measure/Transport mode	Car	Tram	Pedestrian	Bike	Trol	Light HGV
Increase in average speed	6,52%	7,46%	3,03%	0%	0,18%	6,67%
Decrease in average delay	-23,11%	-19,37%	-5,65%	3,03%	-5,82%	-24,1%
Decrease in total delay	-17,46%	-16%	3,15%	-1,58%	100%	-16,79
Decrease in total travel time	-10,17%	-9,49%	2,91%	3,22%	100%	91,45%

Measure/Origin-Destination	AB	BA	CD	DC
Increase in average speed	1,45%	5,34%	4,95%	0%
Decrease in average travel time	-2,52%	-7,54%	-7,37%	0,66%

Measure	Network total
Decrease in average delay	-1,53%

Procedure 10:

Results of Cost/Benefits calculation with recalculation to monetary value show that implementation of ITS (green wave approach) gives monetary economy from the time perspective for one peak hour is a more than 48 EUR. In average 1 year has 52 weeks. By multiplying number of weeks by 5 working days and by estimated monetary benefit of 48 EUR gives us 12480 EUR per year. The costs are not considered here as the traffic light management is done by dedicated enterprise which has supporting contract with Riga city council.

4. CONCLUSIONS

- The main attention of this research was concentrated on impact assessment that leads ITS implementation in the city. In particular work an ex-ante approach was considered. The goal of the research – development of ITS impact evaluation methodology based on ex-ante approach considering the vital factors for Riga transportation system was fully achieved.
- Review of ITS assessment theory was done and different ITS impact assessment methods like CBA and MCA.
- ITS ex-ante impact assessment methodology using microscopic simulation for Riga was developed and approbated on Riga case study. During Riga case study main goals for Riga transportation system development, main problems and main measures for impact assessment were identified. And based on the results from simulation modelling proposed measures and benefits were estimated and the decision for ITS green wave technology was done.
- The potential users of this methodology are decision makers. This methodology can help to understand the influence of proposed ITS solution for the city before the real system implementation. In turn, it may lead for deployment different ITS applications with the best positive effect on the transport network and save money and time.

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