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Proceedings of special session in Young Researchers' Seminars during the 16th International Conference on Reliability and Statistics in Transportation and Communication

alliance

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PANEPISTIMIO THESSALIAS – UTH	Greece
FRAUNHOFER GESELLSCHAFT ZUR FORDERUNG DER ANGEWANDTEN FORSCHUNG EV – Fraunhofer	Germany

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LIST OF ABBREVIATIONS

Abbreviation	Description
RelStat'16	16th International Conference on Reliability and Statistics in Transportation and Communication
Fraunhofer	Fraunhofer Institute for Factory Operation and Automation
GA	Grant Agreement
ICT	Information and Communications Technology
TTI	Transport and Telecommunication Institute
UTH	University of Thessaly
YRS	Young Researchers Seminar
WP	Work Package

ABSTRACT

The deliverable presents the proceeding of Young Researchers' Seminar – special session "Sustainable Transport Interchanges" in frame of the 16th International Conference on Reliability and Statistics in Transportation and Communication (Riga, Latvia, 19-22 October 2016).
In seminar more than 20 young researchers from Latvia, Germany and Greece participated. In total 12 presentations were presented in different sections, 10 of them presented their research in section "Sustainable Transport Interchanges". As a result 8 papers were included in proceeding of Young Researchers' Seminar special session, which was organised during the 16th International Conference on Reliability and Statistics in Transportation and Communication.

1 Introduction

1.1 Contents of the deliverable

Current document is a deliverable in frame of WP3. The objective of WP3 is to define and implement a knowledge-sharing strategy. The strategy clearly defines the activities and plans for activities execution, which must maximize the transfer of knowledge between partners of the project. Knowledge-sharing strategy targets on the following groups of users: researchers and academic staff of TTI; master and PhD students. Deliverable D3.6 is a set of the abstracts and papers presented in Young Researchers' Seminar “Sustainable Transport Interchanges” in frame of the 16th International Conference on Reliability and Statistics in Transportation and Communication by the young researchers from TTI, UTH and Fraunhofer.

Abstracts and papers were submitted from TTI, UTH, Fraunhofer to the 16th International Conference on Reliability and Statistics in Transportation and Communication, which was held on 19-22 October 2016, in Riga, Latvia. And part of them were approved for presentation in Young Researchers' Seminar “Sustainable Transport Interchanges”.

The RelStat'16 Conference was organized by the Transport and Telecommunication Institute. The purpose of the conference is to bring together academics and professionals from all over the world to discuss the themes of the conference:

- Smart Solutions in Transportation Systems
- Networking and Telecommunications
- Reliability, Risk and Safety Applications
- Mathematics, Statistics, Modelling and its Applications
- Information Systems and Information Technologies
- Business and Economics Applications
- Mobile and Distance Education

Accepted and invited abstracts and papers of RelStat'16 were published in the book of abstract with Proceedings of the Conference on CD as appendix (both with ISBN), selected papers will be published in “Procedia Engineering” (during 3-4 months after the Conference) - a journal published by Elsevier. The journal is indexed in Scopus, the largest abstract and citation database of peer-reviewed literature and others databases.

1.2 Project overview

ALLIANCE aims at developing advanced research and higher education institution in the field of smart interconnecting sustainable transport networks in Latvia, by linking the Transport and Telecommunication Institute – TTI with two internationally recognized research entities – University of Thessaly – UTH, Greece and Fraunhofer Institute for Factory Operation and Automation – Fraunhofer, Germany. Close collaboration of TTI with UTH and Fraunhofer will enable the achievement of the goals through the following activities:

- Organization of young researchers’ seminars.
- Organization of workshops.
- Organization of summer schools for trainers and young researchers.
- Development of educational programme for graduate and post-graduate students.
- Development of training programme for trainers and practitioners.

- Provision of grants for participation as authors of peer reviewed publications in conferences.
- Facilitation of Short-Term Staff Exchanges (STSE's) with the aim of international collaboration, mainly publications.
- Establishment of a guidance strategy for preparing scientific publications.
- Creation of an educational forum as on-line tool for distance learning and knowledge sharing.

The overall methodology of the project is built around the analysis of the needs of Latvia and the surrounding region of the Baltic sea (Lithuania, Estonia, Poland) on knowledge gain about intermodal transportation networks and the development of the tools to attain this knowledge, providing at the same time excellence and innovation capacity. The analysis to be conducted during the first stages of the project, steps on the overarching relations among policy makers, industry and education/research.

Structured around three main pillars, organizational/governance, operational/services and service quality/customer satisfaction, ALLIANCE will deliver a coherent educational/training program, addressed to enhancing the knowledge of current and future researchers and professionals offering their services in Latvia and the wider region.

The expected impacts on the overall research and innovation potential of TTI and Latvian research community will be of high importance and TTI will benefit from ALLIANCE by:

- Improving its knowledge in methodologies for preparing, writing and publishing scientific papers.
- Strengthening its research capacity.
- Establishing international research teams in specific areas of interest.
- Generating new innovative ideas for future research work through the project's activities.
- Setting up the fundamentals for the young generation of researchers.
- Being integrated in a number of existing international transportation research networks.
- Being incorporated in the European research system of transport and logistics.

In addition, the cooperation of TTI with UTH and Fraunhofer will induce benefits into several domains of everyday life at regional, national and international scope. New bases will be established concerning knowledge transfer procedures, education and interdepartmental collaboration amongst research institutes. The innovative organizational framework, which will be structured for this purpose during the project, is expected to constitute a best practice application with tangible and well estimated progress results, which will be disseminated and communicated through social events to the research community and to the respective business sector as well.

Lastly, an important benefit will be the configuration of an integrated framework pertaining to the knowledge transfer techniques and the generic upgrading of the educational system with use of networking, staff exchange, webinars and other knowledge transfer methods and techniques based on a well-structured and well-tried schedule.

2 Alliance scientific contribution in RelStat'16

ALLIANCE team encourage young researchers to submit their relevant research in three thematic areas: governance and policy development, smart solutions, decision-making.

In total,14 abstracts were prepared by the young researchers (from TTI, UTH and Fraunhofer) and were submitted for reviewing by the moderators of the Young Researchers Seminar (YRS), members of the the ALLIANCE project consortium:

• Prof. Irina Yatskiv (TTI, Latvia)

• Prof. Eftihia Nathanail (UTH, Greece).

14 abstracts were accepted and the authors received the official notification from the moderators of ALLIANCE YRS and were invited for present their researches within the framework of the 16th International Conference on Reliability and Statistics in Transportation and Communication (RelStat'16), hosted by Transport and Telecommunication Institute in Riga, the capital of the Republic of Latvia, in October 19-22, 2016.

In total, 10 abstracts were chosen for presentation in special session “Sustainable Transport Interchanges” and other were recommended for presentation in other sessions of the 16th International Conference on Reliability and Statistics in Transportation and Communication. The YRS Special Session included papers presenting technical, experimental, methodological and/or applicative contributions in the scope of Sustainable Transport Interchanges.

After the official submission of the abstracts, 8 groups of authors presented the full papers, which are peer reviewed and included in proceeding of special session of Conference after corrections.

The title, the authors, the abstract and keywords for each of these chosen for YRS presentations are included in Tables 1-10. The Conference’s program is given in Annex A, while the full papers are found in Annex B.

Table 1: Presentation1 – Simulation of Ground Vehicles Movement on the Aerodrome

Code:	**1**
Responsible or involved partner:	TTI
Paper title:	Simulation of Ground Vehicles Movement on the Aerodrome
Author(s):	Iyad Alomar, Jurijs Tolujevs, Aleksandrs Medvedevs
Reference:	Alomar, I., Tolujevs, J. & Medvedevs, A., 2016. “Simulation of Ground Vehicles Movement on the Aerodrome”. 16th International Conference on Reliability and Statistics in Transportation and Communication, Riga Latvia, 19-22 October 2016.
Abstract: This research describes the simulation software currently used for modelling of airport operation process, as well as the full description of the developed conceptual model of management of the ground vehicle movement at aerodromes was given. The main purpose of constructing a simulation model is to study the impact of the traffic management on the ground vehicle performance indicators and the safety of aircraft handling processes. One of the major parts of the airlines cost is the cost for ground handling services. To reduce waiting time and downtime of the aircraft on the ground, it is necessary to optimize the use of the resources and the personnel involved in ground handling process. New methods of control start with continuous positioning of mobile objects, and terminating in the transmission of	

individual control commands to the driver's seat. The developed simulation model will be used as a testing bed, on which different methods of data collection about mobile objects at the aerodrome will be used.	
Keywords:	Simulation; ground handling vehicles; aerodrome; optimization; modelling

Table 2: Presentation 2 – Transport infrastructure Development Performance

Code:	**2**
Responsible or involved partner:	TTI
Paper title:	Transport infrastructure Development Performance
Author(s):	Oksana Skorobogatova, Irina Kuzmina-Merlino
Reference:	Skorobogatova O. & Kuzmina-Merlino, I., 2016. “Transport infrastructure Development Performance”. 16th International Conference on Reliability and Statistics in Transportation and Communication, Riga Latvia, 19-22 October 2016.
Abstract: Transport infrastructure is an integral part of the transport system of any city or state. In connection with the development of society and intensification of international relations due to the globalization processes, the importance of transport as a factor for economic and social development has enhanced. Various aspects of the activities related to the development of transport infrastructure have increasingly become the objects of scientific researches. Transportation as an economic factor is a measure of economic activity and at the same time transportation is a reflection of economic activity. So, the questions about transport infrastructure performance measurement and relationship between transport infrastructure and economic growth are the subjects for discussions in both academic and non-academic circles. This paper highlights the role of the transportation industry in economic development of Latvia, describes the concept of transport infrastructure as an important part of the state transport system, and estimates the employed international approaches to the measurement of performance of transport infrastructure development. The article focuses on the necessity for the development of the methodology of measuring the transport infrastructure performance, that should be applied systematically and that would be generally helpful to all responsible people making transportation-related decisions.	
Keywords:	Transport infrastructure, performance, measurement, economic growth

Table 3: Presentation 3 – Evaluating Riga Transport System Accessibility

Code:	**3**
Responsible or involved partner:	TTI
Paper title:	Evaluating Riga Transport System Accessibility
Author(s):	Evelina Budilovich

Reference:	Budilovich, E., 2016. "Evaluating Riga Transport System Accessibility". 16th International Conference on Reliability and Statistics in Transportation and Communication, Riga Latvia, 19-22 October 2016.

Abstract:

Accessibility can be defined as the facility that helps people to reach a location to perform an activity. Providing a link between transportation and land-use models accessibility can be seen as an indicator to assess transport and land-use policies, especially in urban structures.

The research presents an overview of the case study: the accessibility analysis of the Riga public transport system. The transport system of Riga is presented and highlighted by the public transport services; the problems of public transport system and development plans are discussed. The author continues to analyse the project of the Riga Central Multimodal Public Transportation Hub that is planned in the frame of the Rail Baltica project and provides the analysis of the Riga Transport System accessibility in the current moment, before reconstruction.

Accessibility was calculated on the base of the shortest journey time (or the fastest possible route) during the morning peak hours. The public transport accessibility was analysed and compared with the travel time by private cars. For the calculations, the author used Riga transport model, which is created in EMME software and supported by Riga municipality. The list of zones with the high level of travelling time that needs to be improved for more attractive public transport system was determined.

Keywords:	Urban transport system, public transport, accessibility, measures

Table 4: Presentation 4 – Mesoscopic Simulation for Automotive Industry Applications

Code:	4
Responsible or involved partner:	Fraunhofer
Paper title:	Mesoscopic Simulation for Automotive Industry Applications
Author(s):	Sebastian Lang, Tobias Reggelin, Toralf Wunder
Reference:	Lang, S., Reggelin, T. & Wunder, T., 2016. "Mesoscopic Simulation for Automotive Industry Applications". 16th International Conference on Reliability and Statistics in Transportation and Communication, Riga Latvia, 19-22 October 2016.

Abstract:

The paper deals with the evaluation of the mesoscopic simulation concept on a problem from the automotive industry. Mesoscopic simulation is settled between the well known concepts of microscopic simulation (discrete event simulation) and macroscopic simulation (system dynamics). The mesoscopic method is commonly implemented with the discrete rate simulation paradigm, which combines characteristics of discrete event simulation and system dynamics. As system dynamics, discrete rate simulation is a flow based paradigm dealing with stocks and flows but also event driven like discrete event simulation. Mesoscopic models obtain a higher level of detail compared to macroscopic models as also a lower modelling effort and run time compared to microscopic models. Looking on the automotive industry, it is expected that mesoscopic simulation is beneficial to support decisions on the operational and tactical level of planning, where discrete event models are not appropriate. To evaluate this thesis, a mesoscopic model of a goods inwards department of the BMW company will be created and compared with a corresponding discrete event model from BMW regarding simulation results and run time.

Keywords:	Automotive Industry, Logistics Planning, Production Planning, Mesoscopic Simulation, Discrete Rate Simulation

Table 5: Presentation 5 – Socio-technical Innovations in Urban Logistics: New Attempts for a Diffusion Strategy

Code:	**5**
Responsible or involved partner:	Fraunhofer
Paper title:	Socio-technical Innovations in Urban Logistics: New Attempts for a Diffusion Strategy
Author(s):	Evelyn Fischer
Reference:	Fischer, E., 2016. “Socio-technical Innovations in Urban Logistics: New Attempts for a Diffusion Strategy”. 16th International Conference on Reliability and Statistics in Transportation and Communication, Riga Latvia, 19-22 October 2016.

Abstract:

Popular diffusion strategies of technical innovations are so far characterized by a type of linear modelling, following the principles of causal communication chains from the developer to the adopter. From this perspective, neither the consumer nor the technology itself is understood as an actor in the diffusion process. Especially in times in which our understanding of the functioning of social systems increase, we should use this knowledge for the initiation of system change. Diverse environmental, health and economic problems are especially in urban agglomerations of working; living and supply reason enough for implementing a sustainable infrastructure in urban logistics. This paper aims to offer an understanding of technology equally operating with humans in actor networks, which influences our behaviour. So to change our behaviour, we have to start changing our interaction models with technology and offer attractive conditions for more sustainable uses. Thus, the diffusion of an innovation won’t be the question anymore, but the translation of lifestyles into actor networks, like sustainable structures for intermodal interchanges. This paper can be assigned to the area of governance and policy development and should be read as an attempt for the development of systemic implementation strategies in urban logistics.

Keywords:	Actor-Network Theory; adoption; e-mobility, innovation diffusion; socio-technical co-evolution; sustainable urban logistics

Table 6: Presentation 6 – Simulation Techniques for Evaluating Smart Logistics Solutions for Sustainable Urban Distribution

Code:	**6**
Responsible or involved partner:	UTH
Paper title:	Simulation Techniques for Evaluating Smart Logistics Solutions for Sustainable Urban Distribution

Author(s):	Ioannis Karakikes
Reference:	Karakikes, I., 2016. "Simulation Techniques for Evaluating Smart Logistics Solutions for Sustainable Urban Distribution". 16th International Conference on Reliability and Statistics in Transportation and Communication, Riga Latvia, 19-22 October 2016.

Abstract:

Smart logistics solutions have been developed in order to alleviate the adverse impacts of increasing goods' transport in urban areas. However, the effectiveness of these measures can be questioned, if negative impacts during or after solutions' implementation are not considered. Simulation has been proved as valuable tool to evaluate such solutions in advance and support the decision making process. This study contributes in presenting the current state of practice in modelling smart logistics solutions, provides a roadmap in simulation techniques for urban freight transport solutions and improves the knowledge around the patterns currently followed.

Keywords:	City logistics measures; simulation; goods distribution; evaluation

Table 7: Presentation 7 – Methodological Framework for the Evaluation of Urban Freight Transport Interchanges Focusing on Urban Consolidation Centres

Code:	**7**
Responsible or involved partner:	UTH
Paper title:	Methodological Framework for the Evaluation of Urban Freight Transport Interchanges Focusing on Urban Consolidation Centres (UCC)
Author(s):	Michael A. Gogas
Reference:	Gogas, M.A., 2016. "Methodological Framework for the Evaluation of Urban Freight Transport Interchanges Focusing on Urban Consolidation Centres". 16th International Conference on Reliability and Statistics in Transportation and Communication, Riga Latvia, 19-22 October 2016.

Abstract:

Over the last decade, the focus in the domain of freight transport has been set on the investigation of ways to eliminate time and cost in last mile delivery, while continuously upgrading the level of provided services, promoting a number of innovative logistics solutions. One of the most important issues is the optimization of the interconnection amongst the interurban and urban sections of the supply chain, where the role of the Freight Transport Interchanges (i.e. Freight Centres) has been fundamental. The key issue is three fold and the optimum solution lies between: a) the selection of the most appropriate location for the establishment of each facility and b) the identification of the facility's attributes that should much the interest area's needs and c) the evaluation of the concept as considered to be part of the local UFT policies and measures promoted or planned for the area of interest. The answer to the afore mentioned issues is provided through a two level approach incorporating the development of two discrete, but successive decision making supportive evaluation tools. First, a methodological approach is developed in order to provide a solution to the facility location problem for Freight Centres with focus on UCCs. Going one step further, it is combined with the integrated evaluation framework used for the assessment of Urban Freight Transport (UFT) policies and measures, developed within the NOVELOG

project, accordingly modified to meet the UCC concept requirements. Both methodological frameworks enable the assessment of UFT and logistics solutions focusing on Freight Centres and especially UCCs, based on selected performance indicators, incorporating divergent stakeholders' interests and taking into consideration conflicting business models and operations.	
Keywords:	Evaluation, framework, UFT, Freight Centers, UCC, optimization

Table 8: Presentation 8 – Providing Guidance for Transit Managers and Operators in Order to Increase the Quality of Their Services

Code:	**8**
Responsible or involved partner:	UTH
Paper title:	Providing Guidance for Transit Managers and Operators in Order to Increase the Quality of Their Services
Author(s):	Maria Tsami
Reference:	Tsami, M., 2016. "Providing Guidance for Transit Managers and Operators in Order to Increase the Quality of Their Services". 16th International Conference on Reliability and Statistics in Transportation and Communication, Riga Latvia, 19-22 October 2016.
Abstract: At each transfer point and taking into account their minimum generalized travel cost, travellers shape an optimal for them strategy to follow for their trip. This generalized cost, is strongly related with transit quality of service aspects and differentiates among different type of travellers. The quality of a service has mostly been studied in terms of marketing, as it comes from social and business sciences. One of the most known models to assess service quality is the GAP model, proposed by Parasuraman et al. (1985), to investigate the service quality gaps in an organization considering at the same time both costumers' and marketers'/operator's' beliefs, expectations, perceptions and standards. Five GAPs have been examined in terms of this model, between: 1) users' expectations and operators' perceptions of users' expectations, 2) operators' perceptions of users' expectations and service quality specifications, 3) service quality specifications and service actually delivered, 4) service delivery and the communications to users about service delivery and 5) users' expectations and perceived services. The present paper deals with the fifth GAP of the model, known as the quality GAP, as this is the gap that leads users' decision to select a transit service (i.e. if users expect a higher quality level than the one perceived, they tend not to use the service). This GAP has been assessed for the Greek transit system case. An internet based questionnaire was used to collect users' expectations and perceptions of 26 selected transit quality indicators, based on a 5 point likert scale. Following, a decision tree was developed using the J48 algorithm linking users' perceptions and expectations with the overall quality of service assessment. The decision tree analysis depicts the importance of various quality components in the generalized cost estimation. According to research findings, the performance indicator "Availability of information by phone, mail", was the most crucial parameter for the overall assessment of the service, while both performance and importance indicators participated in the tree formulation. Tree paths provide guidance for transit operators and/or decision makers for increasing the quality of their services and at the same time enhance performance efficiency and operation profitability.	
Keywords:	Transit quality of service; gap model, decision trees, j48 algorithm

Table 9: Presentation 9 – Simulation Based DSS Development for Riga Airport Capacity Evaluation (without paper)

Code:	**9**
Responsible or involved partner:	TTI
Abstract title:	Simulation Based DSS Development for Riga Airport Capacity Evaluation
Author(s):	Mihails Savrasovs, Valery Zemlyanikin
Reference:	Savrasovs, M., Zemlyanikin, V., 2016. "Simulation Based DSS Development for Riga Airport Capacity Evaluation". 16th International Conference on Reliability and Statistics in Transportation and Communication, Riga Latvia, 19-22 October 2016.

Abstract:

Riga International airport is largest airport in Baltic States. It has direct flights to over 80 destinations in 30 countries. The statistical data for the last 5 years shows around 5mln. passenger turnover. Riga International airport is important transport hub, not only for Latvia, but also for neibouring countries (Lithuania and Estonia). Passenger traffic statistics of the Baltic Countries for Riga International airport shows, that 45% are from Riga and 55 are from Lithuania (Vilnius, Kaunas) and Estonia (Tallinn). Not looking to the fact, that in 2015 the Ground Handling Department of Riga International Airport and the ground handling services company HAVAS EUROPE achieved a high punctuality ratio, by providing good quality, professional services to the carriers with punctuality ratio of 99.58%, which is an excellent result in the aviation industry, still the strategic goal of airport authorities is to create, maintain and improve positive customer experiences by providing high-quality services. It means that airport should put a lot of attention on developing different types of the information services in order to keep high quality level. In general the information services could be classifies as: user-orientated services (main goal to provide data and services to the end users) and own-orientated services (main goal to support internal activities of airport).

The goal of this article is to present the development of the decision support system (DSS), which is based on simulation application, for Riga International airport. The DSS is orientated on evaluation of the capacity of the airport. Here must be underlined, that capacity here is referenced not to the passenger capacity of the airport, but to the capacity, which is related with serving flights. The choose of simulation for the DSS development was done after analysis of the scientific literature and articles. There are number of examples, how simulation is applied for similar task (Bubalo and Daduna, 2011), (Wijnen et al. 2008). The core of the DSS is the simulation models developed in AnyLogic simulation software. The simulation model aggregates supply and demand model. The supply model represents the infrastructure and resources of the airport, meanwhile demand models defines planes schedule (as planes are demanding for the airport resources).

Keywords:	Simulation, decision support system, capacity evaluation

Table 10: Presentation 10 – Evaluation of Transportation Company Logistics Activities Efficiency (without paper)

Code:	**10**
Responsible or involved partner:	TTI

Abstract title:	Evaluation of Transportation Company Logistics Activities Efficiency
Author(s):	Marina Pliss
Reference:	Pliss, M., 2016. “Evaluation of Transportation Company Logistics Activities Efficiency”. 16th International Conference on Reliability and Statistics in Transportation and Communication, Riga Latvia, 19-22 October 2016.

Abstract:

Logistics activities of a transportation company involve integration of tasks, and especially topical is the choice of methods and means of evaluating the effectiveness of its logistics activities. As the analysis of the sources of modern logistics shows, there is no single point of view regarding the composition and structure of performance indicators of the effectiveness of logistics activities within the scientific community yet. Two problems determine research relevance:

different indicators provide different and often conflicting evaluation results;

the most important or the most general indicator has to be chosen, or some more complex or systemic approach should be used.

The aim of the research is to study and analyse existing approaches for evaluating the effectiveness of the logistics activities of the transport companies.

Basic topics of this research are:

description and analysis of existing logistics approaches for assessing the effectiveness of the transport companies logistics activities;

development of recommendations for improving the methodology for assessing the effectiveness of the transport companies logistics activities.

Keywords:	Criterion, redundancy, benchmarking, costs, key performance indicator

3 Analysis

10 presentations were submitted per ALLIANCE partners for special session "Sustainable Transport Interchanges", five out of ten papers were prepared by TTI representatives from Latvia and the rest five papers by the UTH and Fraunhofer representatives (see Figure 1).

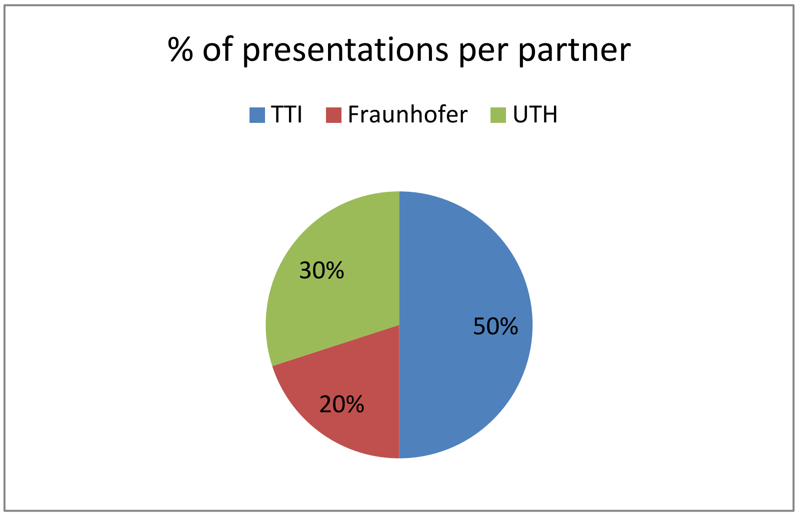

Figure 1: % of presentations per partner

In total, there are 16 authors and co-authors of the presentations. The Figure 2 shows the distribution of authors and co-authors by ALLIANCE partners.

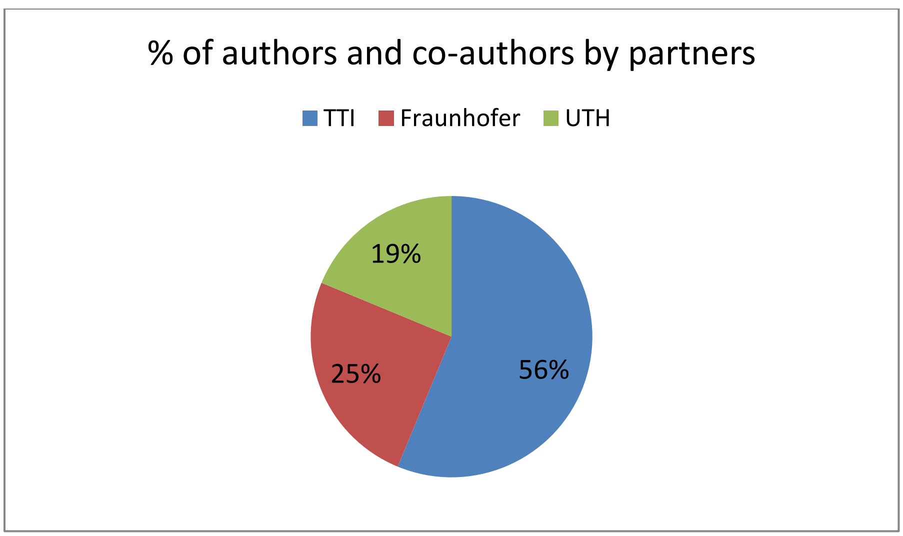

Figure 2: % of authors and co-authors by partner

In addition, the 38% of the authors or co-authors of the presentations were women, and the rest 62% were men, showing a good gender balance (Figure 3).

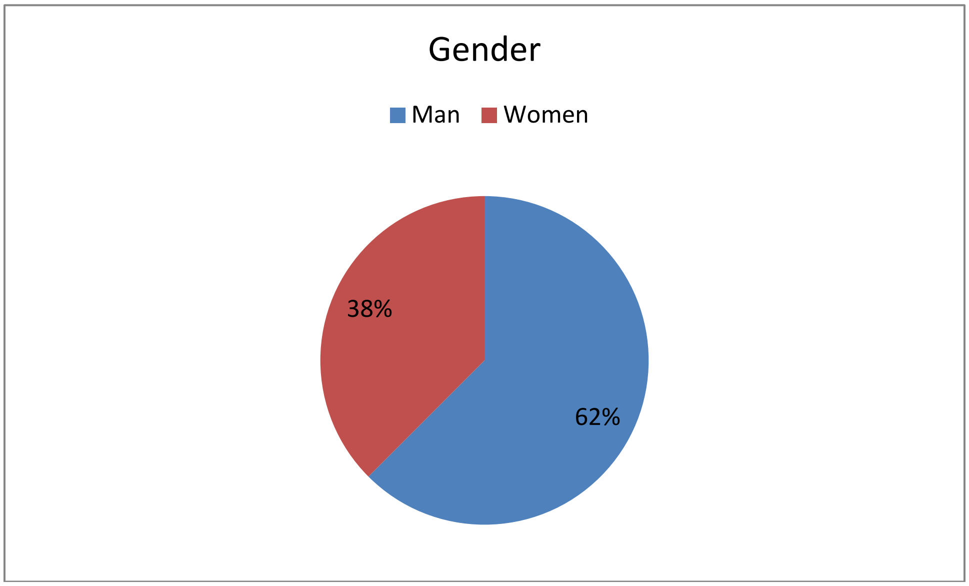

Figure 3: Gender distribution

Lastly, 75% of the authors or co-authors were young researchers and the rest 25% were senior researchers, addressing the scope of ALLIANCE for the active involvement of students and young researchers in its activities (Figure 4).

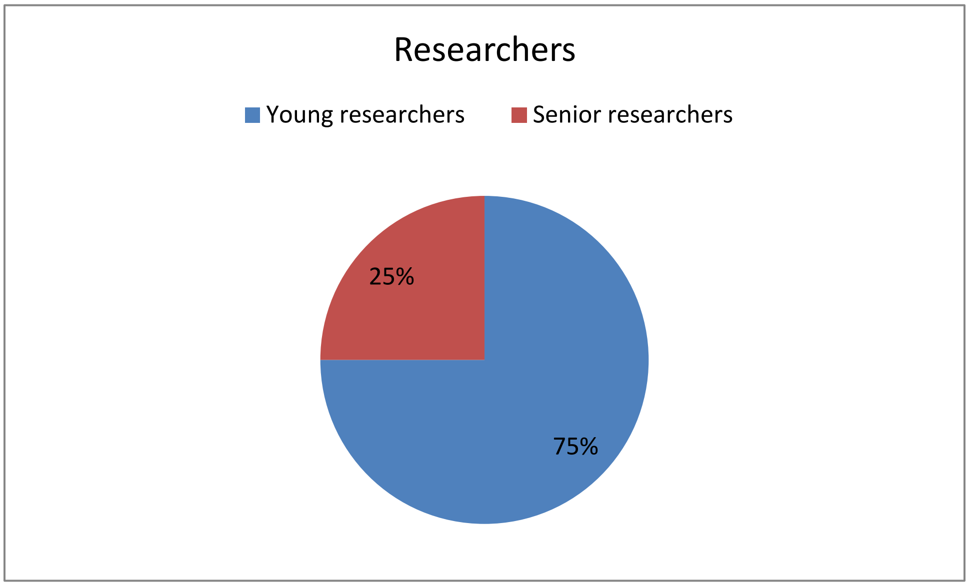

Figure 4: Percentage of young & senior researchers

4 Synopsis

This deliverable is the compendium of the ALLIANCE’s contribution to the 16th International Conference on Reliability and Statistics in Transportation and Communication (RelStat'16) which was held on 19-22 October 2016 in Riga, Latvia.

14 abstracts were accepted and the authors received the official notification from the moderators of ALLIANCE YRS and were invited for present their researches within the framework of the 16th International Conference on Reliability and Statistics in Transportation and Communication (RelStat'16).

In total, 10 abstracts were chosen for presentation in special session “Sustainable Transport Interchanges” and other were recommended for presentation in other sessions of the 16th International Conference on Reliability and Statistics in Transportation and Communication.

Table 11: Overview of the activity

No	Type of activity	Main Leader	Title	Date/period	Place	Type of audience	Size of audience	Countries addressed
1	16th International Conference	TTI	Reliability and Statistics in Transportation and Communication	19-22 October 2016.	Riga, Latvia	Research & academics communities, Local & regional authorities, Transport & terminal operators, Transport policy makers & influencers, Enterprises /Businesses, General public	137 participants	10 abstracts in Special Session and 4 in others

Table 12: Overview of contribution to YRS

No.	Title	Authors	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Contribution	Permanent identifiers (e.g.. link, if available)	Is/Will open access provided to this publication?
1	Simulation of Ground Vehicles Movement on the Aerodrome	Iyad Alomar, Jurijs Tolujevs, Aleksandrs Medvedevs	Compendium of papers presented at the 16th International Conference of Reliability and Statistics in Transportation and Communication	October 2016	ALLIANCE Project	Riga, Latvia	2016	Abstract, paper, presentation	www.alliance-project.eu/deliverables/	Yes
2	Transport infrastructure Development Performance	Oksana Skorobogatova, Irina Kuzmina-Merlino	Compendium of papers presented at the 16th International Conference of Reliability and Statistics in Transportation and Communication	October 2016	ALLIANCE Project	Riga, Latvia	2016	Abstract, paper, presentation	www.alliance-project.eu/deliverables/	Yes
3	Evaluating Riga Transport System Accessibility	Evelina Budilovich	Compendium of papers presented at the 16th International Conference of Reliability and Statistics in Transportation and Communication	October 2016	ALLIANCE Project	Riga, Latvia	2016	Abstract, paper, presentation	www.alliance-project.eu/deliverables/	Yes
4	Mesoscopic Simulation for Automotive Industry Applications	Sebastian Lang, Tobias Reggelin, Toralf Wunder	Compendium of papers presented at the 16th International Conference of Reliability and Statistics in Transportation and Communication	October 2016	ALLIANCE Project	Riga, Latvia	2016	Abstract, paper, presentation	www.alliance-project.eu/deliverables/	Yes
5	Socio-technical Innovations in Urban Logistics: New Attempts for a Diffusion Strategy	Evelyn Fischer	Compendium of papers presented at the 16th International Conference of Reliability and Statistics in Transportation and Communication	October 2016	ALLIANCE Project	Riga, Latvia	2016	Abstract, paper, presentation	www.alliance-project.eu/deliverables/	Yes
6	Simulation Techniques for Evaluating Smart Logistics Solutions for	Ioannis Karakikes	Compendium of papers presented at the 16th International Conference of Reliability and Statistics in Transportation and	October 2016	ALLIANCE Project	Riga, Latvia	2016	Abstract, paper, presentation	www.alliance-project.eu/deliverables/	Yes

No.	Title	Authors	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Contribution	Permanent identifiers (e.g.. link, if available)	Is/Will open access provided to this publication?
	Sustainable Urban Distribution		Communication							
7	Methodological Framework for the Evaluation of Urban Freight Transport Interchanges Focusing on Urban Consolidation Centres (UCC)	Michael A. Gogas	Compendium of papers presented at the 16th International Conference of Reliability and Statistics in Transportation and Communication	October 2016	ALLIANCE Project	Riga, Latvia	2016	Abstract, paper, presentation	www.alliance-project.eu/deliverables/	Yes
8	Providing Guidance for Transit Managers and Operators in Order to Increase the Quality of Their Services	Maria Tsami	Compendium of papers presented at the 16th International Conference of Reliability and Statistics in Transportation and Communication	October 2016	ALLIANCE Project	Riga, Latvia	October 2016	Abstract, paper, presentation	www.alliance-project.eu/deliverables/	Yes
9	Simulation Based DSS Development for Riga Airport Capacity Evaluation	Mihails Savrasovs, Valery Zemlyanikin	Compendium of papers presented at the 16th International Conference of Reliability and Statistics in Transportation and Communication	October 2016	ALLIANCE Project	Riga, Latvia	October 2016	Abstract, presentation	www.alliance-project.eu/deliverables/	Yes
10	Evaluation of Transportation Company Logistics Activities Efficiency	Marina Pliss	Compendium of papers presented at the 16th International Conference of Reliability and Statistics in Transportation and Communication	October 2016	ALLIANCE Project	Riga, Latvia	October 2016	Abstract	www.alliance-project.eu/deliverables/	Yes

ANNEX A: Agenda of YRS "Sustainable Transport Interchanges"

Enhancing excellence and innovation capacity in sustainable transport interchanges
ALLIANCE
(Grant agreement no.: 692426)

Young Researcher Seminar "Sustainable Transport Interchanges"
Agenda

Location: Transport and Telecommunication Institute, Lomonosov street 1, Aud. 130
20-21 October, 2016, Riga, Latvia

20 October 2016	
Time	**Topic**
09:15–10:00	Registration and Welcome Coffee (Aud. 130)
10:00–10:15	**Opening Session.** (Hall#1 – Aud. 130). Moderator: TTI Vice-Rector, Prof. Irina Yatskiv (Latvia) Welcome speech from TTI Acting Rector*, Juris Kanels (Latvia)*
10:15–12:30	**Plenary Session** (Hall#1 – Aud. 130). Moderator: TTI Vice-Rector, Prof. Irina Yatskiv (Latvia) • **Prof. Andres Monzon (Spain)** Methodology to Assess the Effects of ICT-Measures on Emissions. The Case Study of Madrid • **As. Prof. A. Bahillo (Spain)** Blue Care: A Cooperative Location Network for Handicapped Persons • **As. Prof.Ilia Frenkel (Israel)** On Sensitivity Analysis of Aging Multi-State System • **As. Prof.Yulia Stukalina (Latvia)** Management of a Technical University in the Context of Preparing Students for the 21st Century Careers in Science and Technology
12:30 – 13:30	Lunch
13:30–15:30	Parallel Sessions (Session "Transport and Logistics" is recommended for YRS participants)
15:30–16:00	Coffee Break
16:00–18:00	Parallel Sessions (Session "Transport and Logistics" is recommended for YRS participants)
21 October 2016	
Time	**Topic**
Special session **Sustainable Transport Interchanges** Moderators: *Prof. Irina Yatskiv (TTI, Latvia)* *Prof. Eftihia G. Nathanail (UTH, Greece)*	
9:00 - 10:00	**Tutorial** *(Aud. 130)***.** RFID in Logistics and Production – Applications, Research and Visions for Smart Logistics Zones ***Klaus Richter (Fraunhofer, Germany)***
10:15 – 10:35	Simulation Techniques for Evaluating Smart Logistic Solutions for Sustainable

	Urban Distribution ***Ioannis Karakikes (UTH, Greece)***
10:35 – 10:55	Simulation of Ground Vehicles Movement on the Aerodrome ***Alomar, J. Tolujew, A. Medvedevs (TTI, Latvia)***
10:55 – 11:15	Simulation Based DSS Development for Riga Airport Capacity Evaluation ***Mihails Savrasovs, Valery Zemlyanikin (TTI, Latvia)***
11:15 – 11:35	Mesoscopic Simulation for Automotive Industry Applications ***S. Lang, T. Reggelin, T. Wunder (Fraunhofer, Germany)***
11:35 – 11:55	Socio-Technical Innovations in Urban Logistics: New Attempts for a Diffusion Strategy ***Evelyn Fischer (Fraunhofer, Germany)***
11:55 – 12:15	Providing Guidance for Transit Managers and Operators in Order to Increase the Quality of Their Services ***Maria Tsami (UTH, Greece)***
12:15 – 12:35	Development of the Transport Infrastructure of Latvia: Plans and Reality ***O. Skorobogatova, I. Kuzmina-Merlino (TTI, Latvia)***
12:35 – 13:30	Lunch
Time	**Topic**
Special session **Sustainable Transport Interchanges** Moderators: *Prof. Igor Kabashkin (TTI, Latvia)* *Prof. Klaus Richter (Fraunhofer, Germany)*	
13:30 – 14:00	***Invited speaker.*** Technology and Sustainability of Future Supply Chain ***Massimo Merlino (Republic of San Marino, Italy)***
14:00 – 14:20	Evaluation of Urban Freight Transport Policies and Measures: The Case of the Urban Consolidation Center in Graz ***M. A. Gogas (UTH, Greece)***
14:20 – 14:40	Evaluating Riga Transport System Accessibility ***E. Budilovich (TTI, Latvia)***
14:40-15:30	**Round Table.** Possible Subjects for Scientific Collaborations between **TTI-UTH-Fraunhofer** *Moderator: Dr.sc.ing - Mihails Savrasovs (TTI, Latvia)* **Participants:** *Prof. I.Yatskiv (TTI, Latvia)* *Prof. A. Grakovsky (TTI, Latvia)* *Prof. I. Kabashkin (TTI, Latvia)* *Prof. J. Tolujew (TTI, Latvia)* *Prof. I. Kuzmina-Merlino (TTI, Latvia)* *Prof. E.G. Nathanail (UTH, Greece)* *Dr. Lambros Mitropoulos (UTH, Greece)* *Prof. Klaus Richter (Fraunhofer, Germany)*
15:30–16:00	Coffee Break
16:30-17:30	**Meeting for ALLIANCE participants. Discussion future plans based on YRS *(117 Aud.)***

ANNEX B: Papers of special session "Sustainable Transport Interchanges"

The 16th International Conference

RELIABILITY and STATISTICS in TRANSPORTATION and COMMUNICATION (RelStat'16)

19–22 October 2016. Riga, Latvia

Organised by

Transport and Telecommunication Institute (Latvia)
in co-operation with
Latvian Academy of Science (Latvia)

PROCEEDINGS

Edited by

Igor V. Kabashkin

Irina V. Yatskiv

RIGA - 2016

Proceedings of the 16th International Conference *RELIABILITY and STATISTICS in TRANSPORTATION and COMMUNICATION* (RelStat'16), 19–22 October 2016, Riga, Latvia.

Papers were reviewed by the Scientific Committee members;
the responsibility for context and grammar of the papers rests upon the authors.

Transport and Telecommunication Institute
Lomonosova iela 1, LV-1019, Riga, Latvia
http://RelStat.tsi.lv

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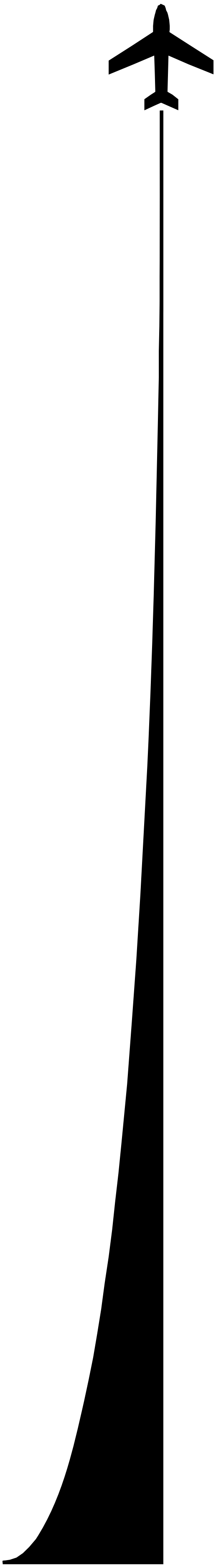

ALLIANCE project SPECIAL SESSION

Sustainable Transport Interchanges

Proceedings of the 16th International Conference "Reliability and Statistics in Transportation and Communication" (RelStat'16), 19–22 October 2016, Riga, Latvia, p. 551–558. ISBN 978-9984-818-83-2
Transport and Telecommunication Institute, Lomonosova 1, LV-1019, Riga, Latvia

SIMULATION OF GROUND VEHICLES MOVEMENT ON THE AERODROME

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This research describes the simulation software currently used for modelling of airport operation process, as well as the full description of the developed conceptual model of management of the ground vehicle movement at aerodromes was given. The main purpose of constructing a simulation model is to study the impact of the traffic management on the ground vehicle performance indicators and the safety of aircraft handling processes. One of the major parts of the airlines cost is the cost for ground handling services. To reduce waiting time and downtime of the aircraft on the ground, it is necessary to optimize the use of the resources and the personnel involved in ground handling process. New methods of control start with continuous positioning of mobile objects, and terminating in the transmission of individual control commands to the driver's seat. The developed simulation model will be used as a testing bed, on which different methods of data collection about mobile objects at the aerodrome will be used.

Keywords: Aerodrome, Ground Handling Vehicles, Simulation, Optimization, Modelling

1. Introduction

One of the major parts of the cost incurred to airlines is the ground handling services. In order to reduce waiting time and downtime of the aircraft on the ground, it is necessary to optimize the use of the resources and personnel involved in the ground handling process.

From another point of view, it is important to maintain aviation transportation at a high level of safety. According to the Indian Director of St. Joseph's College, sustainability is a subject to a wide range of general and specific interpretations, in the general political debate but specifically within the aviation sector and among its stakeholders (Chakrabarti and Anup, 2013).

Eco-efficiency and sustainability is often used as a synonym for eco-efficiency or environmental efficiency and mitigation in the sense of reducing environmental impact per unit of business performance, for instance, per RPK (revenue per kilometre) or aircraft movement. The aim is to "do more with less". The pursuit of eco-efficiency does not imply a constraint on growth in the scale of an activity (Knudsen, 2004).

Bad optimization cannot only affect sustainability, but also it affects external costs, which is a third concept, generally defined as the costs that are not reflected in the price paid by the user / traveller and are therefore not factors attended to in the market (Upham, 2003). Individuals using a given form of transportation are not generally aware of the external costs involved and it is possible that many of these costs may have never been defined. Broadly, the external costs can be defined as costs due to:

- Accidents
- Air pollution
- Climate change
- Noise
- Congestion

Sustainable development requires balancing local and global efforts to meet basic human needs without destroying or degrading the natural environment (Opschoor, 2003). The question then becomes how to represent the relationship between those needs and the environment.

Airports are systems that are part of today's society and an integral part of society's demand for mobility (Knudsen, 2004). While it is well understood that airports create impacts on the environment, it is also acknowledged that they contribute to regional economic benefits and affect society by enabling growth. This "airport system" is realized by using products or services and environmental goods like resources, as shown on Figure 1. It produces products or services and environmental impacts. These operations are part of the economy – whether local or regional – and they interact with the surrounding society. It is the goal of the airport to keep these aspects in balance, and secure the future operations.

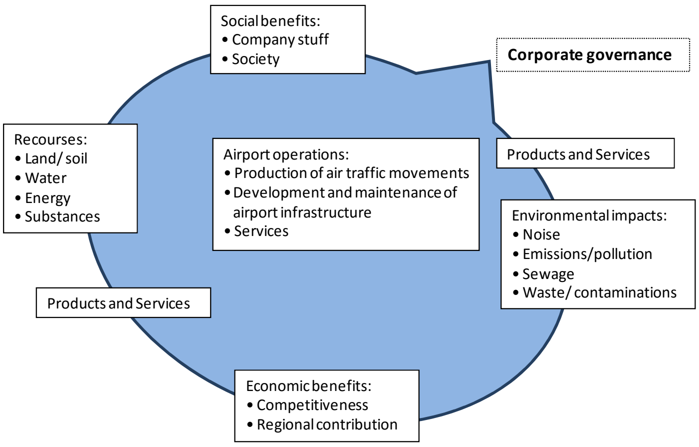


Figure 1. Sustainable Operation of an Airport (Knudsen, 2004)

As stated in (White paper, 2011), transport is fundamental to our economy and society. Mobility is vital for the internal market and for the quality of citizens' life as they enjoy their freedom to travel. Transport enables economic growth and job creation: it must be sustainable in the light of the new challenges we face. Transport is global, so effective action requires strong international cooperation.

The future prosperity of our continent will depend on the ability of all of its regions to remain fully and competitively integrated in the world economy. Efficient transport is vital in making this happen. The EU has called for, and the international community has agreed on the need for drastically reduced world greenhouse gas emissions, with the goal of limiting climate change below 2ºC. Overall, the EU needs to reduce emissions by 80-95% below 1990 levels by 2050.

New technologies for vehicles and traffic management will be the key to lower transport emissions in the EU as in the rest of the world.

Still, the transport system is not sustainable. Looking 40 years ahead, it is clear that transport cannot develop along the path that it is currently on.

The transport industry in itself represents an important part of the economy: in the EU it directly employs around 10 million people and accounts for about 5% of GDP (JRC EC)

The delays incensement in the National Airspace System (NAS) has been the subject of several studies in recent years (Delays to Air Transport in Europe, 2013).

Historical delay data for these airports are summarized. As shown on Figure 2, the various causal factors related to aircraft, airline operations, change of procedures and traffic volumes are also discussed (Mueller and Chatterji, 2002).

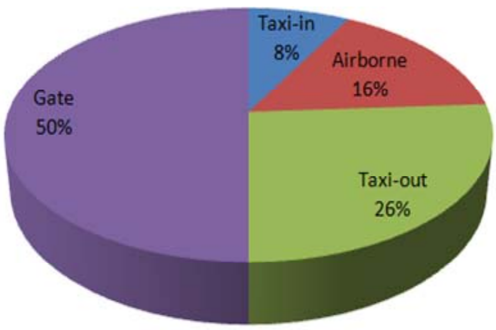


Figure 2. Distribution of delays by phase of flight. (Source: Simio.com)

Given all the above mentioned factors, the researchers started analysing the whole airport operational process, including how to organize the ground operations related to aircraft servicing. Reviewing the most common research, we realize that modelling and simulation is the best way to evaluate and organize this process.

2. Airport simulation approach review

Simulation is a process of creating an abstract representation (a model) to represent important aspects of the real process, (LLC Simio, 2016), for example, just as flight simulators have been used for long time to help expose pilots and designers to both routine and unexpected circumstances, simulation models can help to explore the behaviour of the system under specified situations. The simulation modelling can be used to explore changes and alternatives in a low risk environment.

While reviewing current large-scale simulation models, we note that these models mimic the behaviour of aircraft in complex airspace and airport systems (Trani, 2008). Typically, these models use a discrete event simulation approach to move aircraft among airport and airspace resources.

Airport and airspace resources are considered objects like runways, taxiways, gates and airspace link. Also these models employ some sort of link-node structure to move aircraft entities between resources.

Let us describe the Airport Simulation Models currently in use:

a. SIMMOD: This is the FAA developed model for airport, airfield and airspace simulation in the last two decades (Trani, 2008a), this model provides:
   - a good airfield and airspace logic Gate-to-Gate simulation (important for some applications);
   - 2D graphics (except for workstation version);
   - validated in the period between1985-1991. Cost: $5,900 per copy for SIMMOD Plus! version 7;
   - large learning curve (in general for SIMMOD).
b. RAMS: Reorganized Mathematical Simulator model (Trani, 2008b). An airspace simulation model developed by Eurocontrol. This models has the following characteristics:
   - dealing only airspace simulation;
   - developed using MODSIM - a simulation language developed by CACI (California Analysis Center, Inc), (Kuhl, 2005);
   - good aircraft conflict detection and resolution.
c. TAAM: Total Airspace and Airport Modeler. This simulation model is developed by Preston Group, now part of the Boeing, Jeppesen (Trani, 2008c). This model has:
   - good airfield and airspace logic;
   - gate-to-gate simulator (important for some applications);
   - excellent graphics.

After reviewing of the above 3 models we can deduce:

- delays are usually defined as the difference between unimpeded and actual travel times;
- estimate utilization of airport resources (such as gates, runways, taxiways, etc.);
- these models do not measure capacity directly. Capacity is a non-observable variable in an airport system (can be estimated measuring delay);
- principles of discrete-event simulation (applies to all three models);
- the simulation moves from one scheduled event to the next one;
- keeps tracking the simulation events in an orderly fashion;
- many internal events are generated for each external event;
- the simulation clock is based on the current event’s scheduled initiation, not on elapsed clock time.

3. Airport Simulation Software

According to the latest report by the International Air Transport Association (IATA), an indication of a stabilizing economy is that of passenger and cargo volumes beginning to creep upward again. But ridership is not the only thing changing. Fuel costs rise, prices are drop, all whilst airport authorities and their partners must do their best to find ways of operating at lower costs and looking for ways of focusing their investments to get the biggest “bang for their buck” (LLC Simio, 2016).

In this case a huge question arises, how to prepare for the incensement in passengers and cargo volume while operating under such tight cost constraints?

How landside, terminal and airside sectors can work together not only to accommodate the incensement in passenger and cargo volume, but also to meet and exceed key performance indicators?

To cope with this challenge, the Simio Simulation Software was developed (Pegden and Sturrock, 2013).

With Simio, airports have the power to use simulation as a way of testing ideas on improving individual systems and get a larger perspective on how those adjustments will affect the entire organization. Groundside, terminal and airside sectors can model their systems accurately, make adjustments in a 3D environment, choose an effective course of action objectively, and communicate their ideas for the improvement of the entire system.

Simio provides the ability to:

- sense situational awareness, this being made possible only with simulation;
- model the system quickly and accurately using customizable objects in a code-free environment;
- test ideas without compromise in a straightforward, 3d environment;
- improve system performance with the kind of objective data made possible only with simulation;
- meet or exceed key performance indicators by testing ideas designed to maximize existing resources under difficult budget constraints.

To get a good model in simulation, the system will be too expensive, due to the huge and complex inputs that are required to provide valuable results. Also good models must give us an expectation of the process as a whole and what results we can get. A good model must allow us to add or removed some inputs depending on the situation and area of application.

Airport Research Centre GmbH propose to use CAST Ground handling simulation for aircraft servicing. They had realized that minimizing the duration of aircraft on the ground is vital to an airline's success.

Airport simulation is the computer-based modelling of any real-world process within an airport environment (Greenwood, *et al*., 2011). Simulation allows organizations in the industry to analyse and experiment with their processes in a virtual setting, reducing the time and costs that are associated with real world testing. Runways, gates and luggage services can be properly arranged and assessed within a simulation model, providing companies the opportunity to determine how best to fully utilize their resources at the lowest possible cost. This simulation uses FlexSim, which is powerful yet easy-to-use software for simulation. A comprehensive and innovative simulation engine is hidden behind drag and drop controls, drop-down lists and many other intuitive features that make it accessible for anyone to experiment with a model. All simulation models are created to scale and they are presented using 3D visuals, so it becomes easy to see and recognize bottlenecks in the supply line or other deficiencies within the system. FlexSim also gives decision-makers the tools to confirm their observations, with impressive statistical reporting and analysis incorporated into the software.

All airport operations require a high level efficiency in all fields (fuel service, security, ground handling, etc.). In addition the demand for airport operations rapidly increases year by year. Airport managers and authorities have to ensure that all operational procedures are safe and affordable. This can be done only by using a modelling and simulation system. In one word we need to SIMULATE airports.

In order to optimize ground vehicular movements at aerodromes, a computer simulation can be used for the purpose of testing new methods of transport movement control. Also, the methodology of the simulation model, and structure of the model, which has been designed to optimize transport flows during movements of airport ground vehicles, including aircrafts, is demonstrated in this article.

The developed model will be used to conduct experiments, which may help to find more effective airport ground processes and control techniques.

Such models can be created for any airport. Thus, we can analyse the effectivity of implementation of new control technologies regarding ground vehicles at aerodromes including the aircraft themselves.

In this article we plan to set up a dynamic model and will try to solve two tasks:

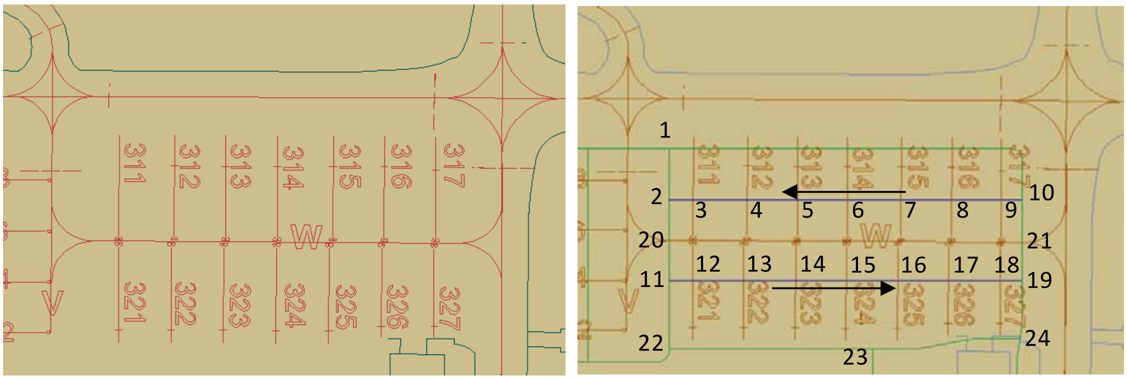
- The analysis task, which is used to determine the limits of the control algorithm's efficiency, for any given type of monitored event; in other words, what technical means will be used to provide the monitoring of relevant events.
- The synthesis task, which is used to determine the types of monitoring of events and the appropriate technical means to be used, which are required for the implementation of the predetermined control algorithm.

4. Description of the conceptual model

The main purpose of constructing the simulation model is to study the impact of the ground vehicle movement management methods on the performance indicators, and the safety of aircraft handling processes. This conceptual model is the first step in the development of simulation modelling of the process of movement of aircraft and ground vehicles at the aerodrome. Using new constructed model, new methods of management of the ground vehicle movement will be analysed. For this purpose, the study will start with continuous monitoring of all mobile objects’ position and should finish with transmission of individual control commands to the driver's working station.

The spatial model of the object of study

A sample of the airfield "Riga International Airport” was selected as the object of study and modelling. Figure 3a demonstrates the location of taxiways on which aircraft move between the runway and ramp area (stands), with the numbers 311-317 and 321-327. Figure 3b illustrates the further path of movement of ground vehicles within the confines of the airfield. On track sections 10-2 and 11-19, only one-way traffic is allowed and on the remaining sectors - two-way traffic. At the points 3-9, 12-18, 20 and 21, the path of movement of ground vehicles intersect with taxiways, which carry moving aircraft. Points 1, 2, 10, 11, 19, 22, 23 and 24 are three-way crossroads, on which ground vehicles intersect.



a) b)

Figure 3. Modelled fragment of the Aerodrome Ground Movement Chart (ICAO)

Types of moving objects

Movable objects which are displayed in the model are; the aircraft (AC) and ground vehicles (GV). Included within the GV definition are the following types of objects:

- Buses for passengers transportation;
- Dolly (luggage carts for transportation ULD);
- Tugs (tractors for transporting Dolly);
- Other vehicles involved in the servicing of aircraft (ladders, aircraft towing trucks, refuelling tankers, catering, potable water service, wastewater service etc.).

AC has absolute priority of movement on taxiways, and their movement control will not differ from the standard, as per ground movement controller orders. The primary focus of the model will therefore be on traffic management of the GV.

Models of crossing points

Figure 4a shows a conceptual model of the crossing point of movement paths of GV and AC taxiways. At the time when the moving object (AC or GV) reaches the appropriate decision point, the driver receives from the ground movement controller one of two directives for further action: to continue the movement; or to stop at the holding position (“waiting point” on diagram). After stopping at the holding position, the driver awaits permission to continue movement. Certainly, the directive to stop at the holding point applies almost exclusively to the movement of GV, while for the AC it may optionally be applied, for example, in the event of an emergency stop of a GV at the crossing point zone. Conditions to grant permission to proceed through the crossing point of the GV are generally the absence of danger of collision with AC, and there being sufficient space for the entry to the next segment. The model shown in Figure 4a, should be applied at the points 3-9, 12-18, 20 and 21 shown in Figure 3b. At the same time points 3-9 and 12-18 must take into account the fact that AC may traverse the crossing point in both directions. At points 20 and 21 the AC and the GV can move in both directions.

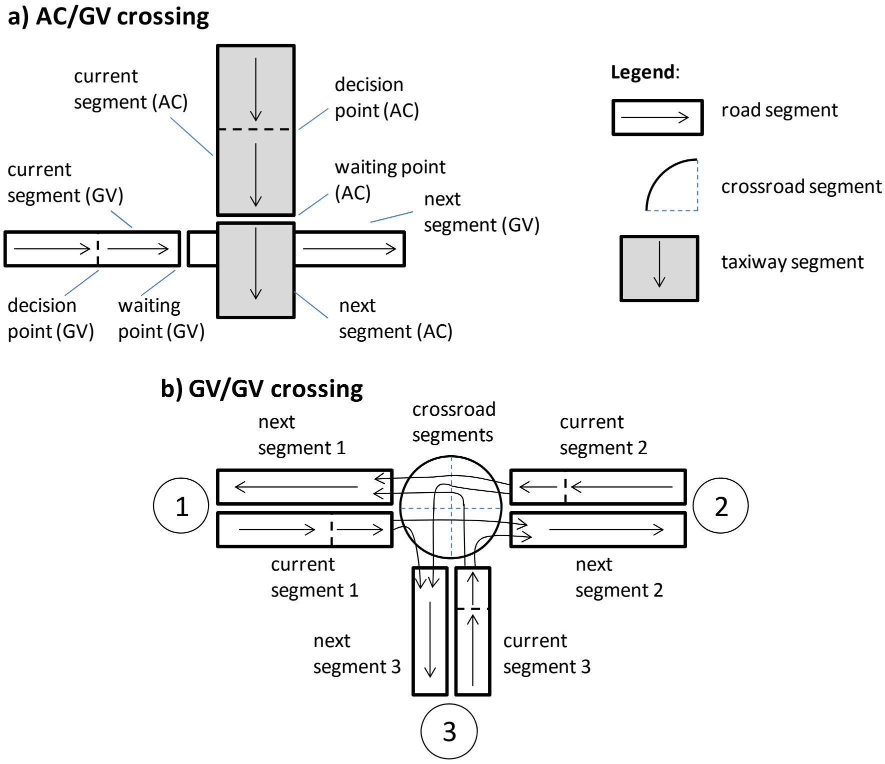


Figure 4. Conceptual models of aerodrome crossing points

Figure 4b shows a conceptual model of a trilateral intersection, at which only GV crossing. At the decision points and holding points, a similar action to that described above is performed. The model is composed of four intersection area, which is named "crossroad segments". Conditions to grant permission to passage the intersection point of the GV in general terms are: the intersection sectors are unobstructed and there is sufficient space to enter the next segment.

The model shown on Figure 4b must be applied at the points 1, 2, 10, 11, 19, 22, 23 and 24 of Figure 3b. In this case points 2 and 19, direction 3 (see Figure 4b) are used for simulation purposes only for the GV arriving at crossroads, and at the points 10 and 11 – for simulation purposes of only those GV, which leave the intersection after its passage.

Data collection and the controller algorithms

For the modelling process, it is necessary to collect the data on the current location of both moving objects: AC, and GV. Their coordinates are stored in the ground traffic control system in the form of a dynamic database. In the management and control system database, the planned routing of each GV in the movement process are stored. The composition of each path includes sequential road segments, which must be used by a particular GV. At the moment when the GV reaches a decision point, it sends a request to the controller of the ground surface movements. The control system automatically analyses the situation, relevant to that particular GV from which the request was received, and generates commands which are sent to the GV driver control panel.

As noted above, there are three types of such commands:

- continue the movement after reaching the decision point;
- stop before the next holding point;
- restart movement after being held at the holding point.

The model provides the ability to set parameter values, thus determining the speed and accuracy of the positioning of the moving objects, based on the types of technical devices used for this purpose.

Aircraft service scenarios and flow models

Traffic intensity of GV is determined by the number of AC located at the airport parking locations at any given time. For the service process of each AC, the parameters of movements of separate GV (trip parameters) may be preset towards the parking locations, and in the opposite direction. The parameters of each trip of GV are, first of all, the name and coordination of the start and end points of the trips, commonly referred to as "source" and "target". Since the model shows only a sample of the airfield, as the points at the boundaries of this sample, points 1, 22, 23 and 24 are used (see Figure 3b). These points particularly can be set up as external source and target. As internal source and target parking areas with numbers 311-317 and 321-327 are defined.

This model should provide the opportunity to describe the scenario of the service of any number of AC for a few hours of the day.

The results of modelling

The main results of the modelling are supposed to evaluate the AC service performance at various optional routing of GVs and the traffic management strategies of GVs. A separate group of indicators should predict the possible delays of the commencement of the AC handling process due to the late arrival of GVs. The other group of indicators should refer to the movement processes of GVs in the transport network and to predict the waiting times of GVs at intersections. A computer animation will provide a graphical illustration of flow processes of AC and GVs at the aerodrome.

5. Conclusion

The conceptual model and the task setting were developed in this research to be used as a testing bed, on which different methods of data collection about mobile objects at the aerodrome, and based on these methods, ground surface movement control strategy, will be studied.

In the above described conceptual model, as the parameters of the status of objects, only the data related to the location of objects are used. The next step of model development will also take into consideration other parameters of the status of the objects, for example, the assigned arrival time of GVs to the parking area.

By means of assigning the system of priorities, which take into consideration the current status of the separate GVs, it will be possible to speed up their movement in the transport network and reduce undesirable delay in the commencement of the AC ground handling process.

Implementation of Higher referred models should allow to make airports more effective as well as safer in terms of ground vehicles movement.

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TRANSPORT INFRASTRUCTURE DEVELOPMENT PERFORMANCE

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Transport infrastructure is an integral part of the transport system of any city or state. In connection with the development of society and intensification of international relations due to the globalization processes, the importance of transport as a factor for economic and social development has enhanced. Various aspects of the activities related to the development of transport infrastructure have increasingly become the objects of scientific researches.

Transportation as an economic factor is a measure of economic activity and at the same time transportation is a reflection of economic activity. So, the questions about transport infrastructure performance measurement and relationship between transport infrastructure and economic growth are the subjects for discussions in both academic and non-academic circles.

This paper highlights the role of the transportation industry in economic development of Latvia, describes the concept of transport infrastructure as an important part of the state transport system, and estimates the employed international approaches to the measurement of performance of transport infrastructure development. The article focuses on the necessity for the development of the methodology of measuring the transport infrastructure performance, that should be applied systematically and that would be generally helpful to all responsible people making transportation-related decisions.

Keywords: transport infrastructure, performance, measurement, economic growth

1. Introduction

Latvia transport system provides an appropriate infrastructure basis for facilitating the growing trade flows between the European Union and Russia/CIS. It also serves to the needs of local export/import operators: free ports in Ventspils, Riga, and Liepaja, an extensive and functional road network, connecting both European and CIS road networks. It is also important for Latvia ports, the shortest route between the EU and the CIS, specialized, high-capacity railway corridor linking Latvian ports with Russia and the Far East, Riga International Airport, pipeline systems for transit and distribution of Russian oil/natural gas (LIAA, 2015).

Studies conducted by the reputable international institutions show rank of Latvia on several prominent international measures presenting the interest for potential investors. According to the World Bank's Doing Business Report 2015, Latvia is ranked 22th out of 189 countries in terms of ease of doing business. At the same time, Latvia is ranked 49th out 189 countries in terms "Protecting minority investors" (http://www.doingbusiness.org/rankings). According to the Global Innovation Index (GII) 2016 Report, Latvia is ranked 35th in terms "Logistic performance index" with score 62.9 and value 3.4 (for comparison: Germany is ranked the first with score 100 and index value equal to 4.1) (https://www.globalinnovationindex.org/analysis-indicator). These factors indicate the investment attractiveness of Latvia for capital expenditure to the transport industry, designated as a priority sector in terms of strategic development of the country. Increase of the investments in transport development determines the urgency of the analysis of the investments effectiveness and enhances the requirements for the financial information disclosure. Thus, it is necessary to study the productivity effects of transportation activity and to design the methodology of measurement of transport infrastructure performance.

The goal of the research is to examine existing approaches of performance measurement of transportation industry activity, especially for transport infrastructure, basing both on the analysis of the scientific and academic publications, and on the official publications of internationally recognized professional institutions working on the subject of the study.

To achieve the goal of the research, the following objectives have been stated:

1) to describe the role of transport infrastructure in the economy of Latvia;
2) to determine is there an appropriate methodology to measure the development performance of the transportation industry, especially transport infrastructure;
3) to identify are there any general indicators of transport infrastructure and economic growth that could be implemented systematically.

The choice of *methodology* used in this study has been determined by the logics of solving the research issues and by the necessity to achieve the research objectives. Consideration of the role of transport infrastructure in the overall transport system is important for determining the components, which form the concept of “transport infrastructure”, and for defining what potential impact they could have on the transport infrastructure performance. Analysis of the official data published by the state institutions of the Republic of Latvia and in the articles of Aldis Bulis and Roberts Skapars (2013), Klaus Schwab (2015) has proved the priority of transport sector development for the economy of Latvia. High country ratings, estimated by the reputable international institutions demonstrate the attractiveness of the sector under discussion for investment. To evaluate the results of the development of the transport infrastructure in the international aspect, the calculation methodologies of Global Competitiveness Index (GCI) and Logistics Performance Index (LPI) have been implemented.

Analysis of economic literature shows that relationship between transport and the economy is discussion question in both academic and non-academic circles. Statistical analysis has been performed to confirm the relationships between economic growth and transport industry development.

The results of this study confirmed the relevance of the examined subject; further studies may be aimed at the study of the capabilities for measurement of different aspects of transport infrastructure (potential infrastructure indices) and for the development of a general indicator for measuring the contribution of transport infrastructure at the industry level, and at the entire economy level also.

2. Transport infrastructure

2.1. Definition

The term “infrastructure” is used on various scientific and non-scientific fields. It originates from Latin, and namely the word “infra” is understood as grounds or fundamentals while “structure” means distribution of elements of certain undefined setup. By the definition that is given in the Cambridge Advance Learner’s Dictionary&Thesaurus (2016) “infrastructure” is the basic systems and services, such as transport and power supplies, that a country or organization uses in order to work effectively. Infrastructure is a component of the territorial structure of national economy, which is formed by the transport, communications, trade, energy and water management system, as well as dwellings, schools, objects of health protection, culture, sports and other objects for care of inhabitants and their arrangement in any territory (Saeima, 2010). Russian researches Rudneva and Kudryavtsev believe that transport infrastructure is a regional transport infrastructure capital, i.e. “a certain type of capital demonstrating the specific social character, manifested in transport infrastructure ability to bring to the region the benefits with not only economic, but also with socio-cultural characteristics, and conditioning the synergistic effect of its implementation” (Rudneva and Kudryavtsev, 2013).

Infrastructure is a complex field with so many different components under it; but all of them can be categorized into two main types of infrastructures. They are the hard and the soft infrastructure. *Hard Infrastructure* refers to the physical network that keeps an industrialized nation smoothly functional. Among the components that are classified under the hard infrastructure are the capital assets like the utilities, transport vehicles, telecommunication systems, roads, highways, railways, subways, traffic lights and street lights, dams, walls and culverts, drainage systems, the airports and bus terminals, and bridges, among others.

The *soft infrastructure*, on the other hand, is the framework required to keep and maintain the different institutions. This can also include both the physical and the non-physical assets. Examples of physical assets are the buildings that house the network and the equipment used to maintain the institution. For non-physical assets, this includes the software and programs, the governing rules and regulations, the financial system, and the organizational structure. In essence, the soft infrastructure embodies the system of delivery of services to the people.

Transport infrastructure is one of the most important elements of the infrastructure nowadays. Transport infrastructure facilitates the development of connections between regions within a country and between countries, and consequently, it supports the formation of mutual economic, social, cultural relations.

2.2. The place of transport infrastructure in the transport system

To evaluate the results of the transport infrastructure development, first of all it is necessary to determine the role of transport infrastructure in the overall system of transport and logistics. This approach allows identifying the factors and conditions that affect the transport infrastructure development; in the future, it can assist in determination of the range of measurement indicators and characterization of the transport infrastructure pace of development. Two points of view on the transport infrastructure position in transportation system and its place and role in logistics infrastructure are given below. The role of transport infrastructure in the system of transportation is shown in Figure 1.

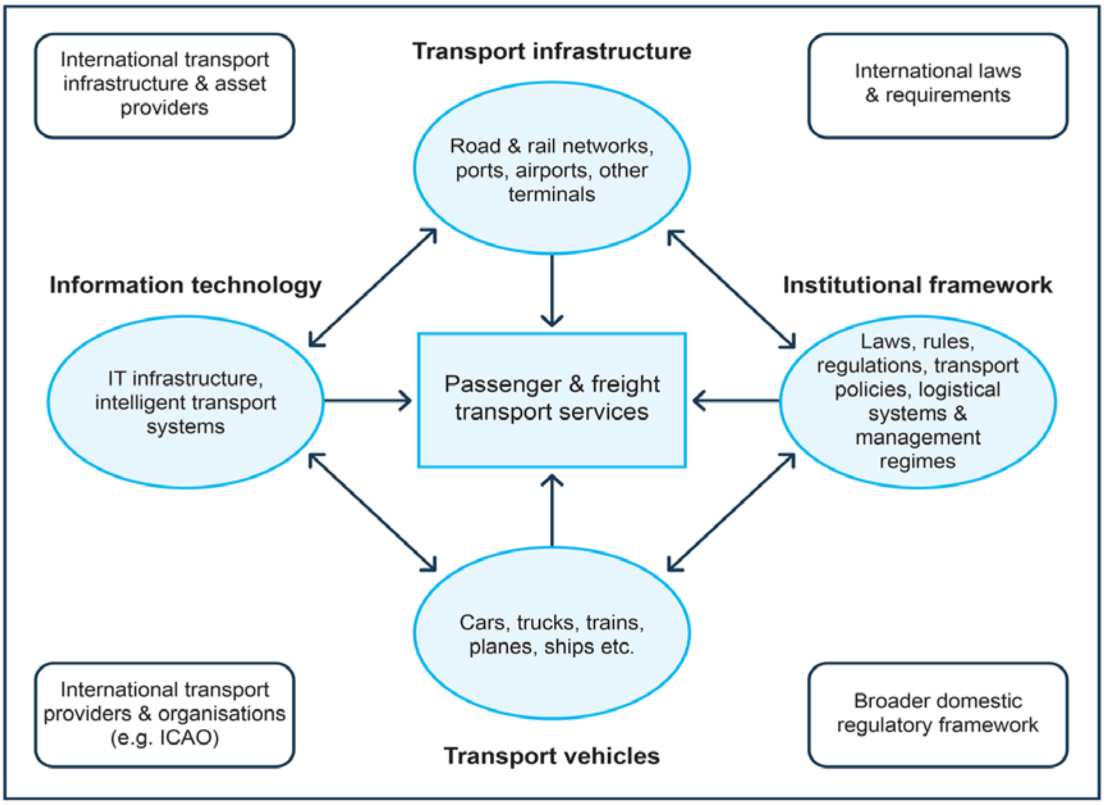

Figure 1. Stylized diagram of the transport system
(adapted by Ministry of transport of the New Zealand in 2014 from Lakshmanan and Anderson, 2002)

It is generally assumed that the logistics infrastructure which conditions the effective performance of the logistics processes comprises "technical means, manners to handle them and systems of how to use them" (Grzelakowski, 2014). Therefore, the logistics infrastructure is a set of various facilities, equipment and means and technical devices which facilitate the completion of the logistics processes in the logistics micro- and macrosystems. The logistics infrastructure within such meaning of the concept comprises:

- warehousing infrastructure, including: buildings and premises, storage yards, warehouse equipment,
- the so-called handling infrastructure, including: internal transport, auxiliary equipment for commodity handling,
- transport infrastructure,
- transport packaging infrastructure: marked with a code, not marked with a code,
- IT infrastructure, including: hardware, software, orga-technical means, equipment for telecommunication purposes.

Transport infrastructure within this concept as a part of logistic infrastructure means the following: air transport, rail transport, road transport, water and inland transport, pipelines, etc.

3. Latvian transport infrastructure

Latvia is located on the eastern coast of the Baltic Sea. One of the priorities of the development of Latvia is a development of safe, sustainable and environment-friendly transport system, in particular multimodal transport. The main objective of sustainable development of transport in Latvia is an integration of the transport infrastructure with the trans-European system. Special attention is directed on the development of along-coast shipping and combined transport. The main elements of the Latvian transport infrastructure comprise:

- Riga international airport;
- Free port of Riga and other ports in Ventspils and in Liepaja;
- Railway transport;
- 33 international coach terminals;
- City public transport;
- Dense and functional networks of roads which are connected with the EU and CIS networks and Latvian ports;
- Special high-capacity railway corridor that connects Latvian ports with Russia and the Far East.

Latvia recognizes the development of an effective, secure, multi-modal, balanced, environmentally friendly and competitive transport system to be a priority (LIAA, 2014). The main goal for the sustainable development of Latvia transport system is to integrate fully Latvia transport infrastructure with the Trans-European multi-modal transport system. In developing the transport and energy infrastructure of the European Union, essential conditions are as follows: the effective use of the transport and energy network; planning the development from an economic point of view, taking into account established goods and passenger transport corridors; and the development potential of economic relations between the European Union and neighbouring countries.

The transit sector is one of the strongest industrial sectors in Latvia. Nearly 90% of turnover in Latvian ports, more than 80% of rail cargo, and the major proportion of oil and oil products transported via trunk pipeline systems is transit. More than 8 % of Latvia's employees are engaged in the transportation and servicing of transit cargo. The importance of the transport, transit and storage sector in terms of GDP contribution is substantial at around 8 % in 2014 (LIAA, 2015) and 9.5% in 2015 (LIAA, 2016). Competitive labour and favourable government policies aimed at improving transport infrastructure, promoting railway freight, simplifying customs procedures with Russia and promoting the use of ICT and new technologies further contribute to the potential of the sector.

What are the plans of government of Latvia in this connection? Transport issues have been discussed in all national-level policy planning documents, the most important of which “Sustainable Development Strategy of Latvia until 2030”, where is written that one of the main objective is “to promote the development of Latvia as transit state, as well as will ensure more efficient co-operation platform in international scale” (Saeima, 2010). Table 1 shows the priority plans of development of transport infrastructure.

Table 1. Strategy of Sustainable Development: special development perspectives (Saeima, 2010, page 101)

	From (2010)	2030
Number of inhabitants (mill.)	2,26	>2,02
Gini coefficient	38	< 30
Motorways with black asphalt from regional state motorways (%)	75.4	100
Number of foreign tourists who are staying for 4 days and more (mill., per year)	0,4	>1,5
Freight turnover in ports of Latvia (mill. of tons per year)	63,6	>130
Passenger circulation in public transport (mill. of passenger kilometres of scheduled traffic buses per year)	2487	2850
Number of the serviced air traffic passengers in the airport —Riga‖ (mill., per year)	3,69	>10
Passenger circulation in railway transport (mill. passenger kilometres per year)	951	1150
Number of the services passengers in the Riga Port (thous., per year)	503,6	>1500

The tasks of transport infrastructure development are considered in the context of solving economic and social problems and environmental problems; it allows achieving the long-term economic development of Latvia. Statistical data demonstrate the active development of the transport industry, which government documents declare as a priority direction of development of the economy of Latvia. Therefore, it can be argued that the relevance of the development of transport infrastructure in Latvia is increasing. In this regard, scientific interest in the object of study is enhancing.

4. Transport infrastructure development performance

Different approaches are implemented to evaluate the results of development of transport infrastructure in international aspect. The most famous are as follows:

- assessment of transport infrastructure on the basis of the calculation of the Global Competitiveness Index (GCI), by using the World Economic Forum.
- evaluation of the supply chain service delivery based on the evaluation of Logistics Performance Index (LPI), which was developed by the World Bank in 2007.

The Global Competitiveness Index (GCI) measures the level of competitiveness of an economy, which is defined as the set of institutions, policies, and factors that determine the level of productivity of an economy. Measurement of the level of transport infrastructure is one of the parts of total evaluation of the GCI. The Logistics Performance Index (LPI) analyses differences between countries in terms of customs procedures, logistics costs and the quality of the infrastructure for overland and maritime transport.

The Global Competitiveness Index (GCI)

The World Economic Forum based on the Global Competitiveness Report 2015-2016 evaluates 140 of the world's economies on the quality of their transport infrastructure; it assesses roads, railroads, ports and air transport, as well as the airline seat kilometres available per week. Top spot in 2014 ranking goes to the United Arab Emirates, with a score of 6.6 (World Economic Forum, 2015). In addition to the Netherlands, other European nations appear on the list, with Spain in sixth, France in seventh and Germany in eighth. The top 10 is completed by Japan, the United States and Malaysia.

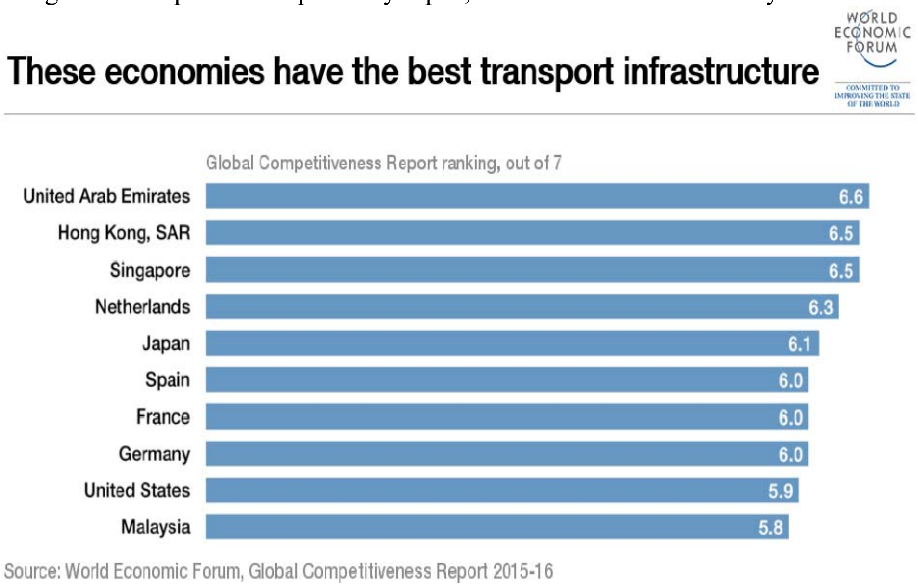

Figure 2. The best transport infrastructure (World Economic Forum, 2015)
Score: 1 = extremely underdeveloped—among the worst in the world; 7 = extensive and efficient—among the best in the world

The data for the ranking is taken from the Forum's Executive Opinion Survey and the International Air Transport Association. According to the global competitiveness ranking in the infrastructure area in period of years 2014-2015 the leaders among the Baltic States are Finland, Germany and Denmark, as evidenced by the data of Table 2. Lithuania, Latvia and Poland have the least competitiveness among the Baltic States.

Table 2. The Global Competitiveness Index 2014–2015: Infrastructure (Schwab, 2015)

Country/Economy	Rank	Score
Germany	8	6.09
Finland	19	5.60
Denmark	21	5.59
Sweden	22	5.55
Estonia	38	4.85
Russian Federation	39	4.82
Lithuania	43	4.73
Poland	63	4.24
Latvia	**47**	**4.61**

Calculation of the GCI is based on the definition of sustainable competitiveness. The model of calculation of GCI index is adjusted by factors that encompass social and environmental sustainability. The GCI index is a comprehensive index that takes into account 12 pillars or drivers: institutions, infrastructure (including transport infrastructure), macroeconomic environment, health and primary education, higher education and training, goods market efficiency, labour market efficiency, financial market development, technological readiness, market size, business sophistication, and innovation. Therefore, infrastructure (including transport) is one of the 12 measurable pillars of the GCI.

Table 3. The Global Competitiveness Index of Latvia in detail (Schwab, 2015)

INDICATOR	VALUE	RANK/144
Quality of overall infrastructure	5.0	40
Quality of roads	3.1	108
Quality of railroad infrastructure	4.1	30
Quality of port infrastructure	5.2	31
Quality of air transport infrastructure	5.4	35
Available airline seat km/week, millions	69.3	94

Note. Value: 1 = extremely underdeveloped—among the worst in the world; 7 = extensive and efficient—among the best in the world

Table 3 data present the indicators that have been taken into account calculating the level of infrastructure of Latvia. The quality of Latvian roads, for example, is estimated very low.

Logistics Performance Index (LPI)

As it has been mentioned above another internationally recognised measure of the development of transport infrastructure is the Logistics Performance Index (LPI).

The first worldwide Logistics Performance Index (LPI) was developed by the World Bank in 2007 to provide a better assessment about how respective countries rank in the managerial and physical effectiveness of their logistic. LPI is the weighted average of the country scores on the following six key dimensions: (1) efficiency of the clearance process by customs and other border agencies; (2) quality of transport infrastructure and information technology; (3) ease and affordability of arranging international shipments; (4) competence and quality of logistics services; (5) ability to track and trace international shipments; and (6) timeliness of shipments in reaching destination. LPI values range from 1 (worst) to 5 (best) and show that building the capacity to connect firms, suppliers and consumers, is a key in a context where predictability and reliability are becoming as important than costs in sourcing decisions. A value of less than 3.0 usually reflects an array of problems within a nation's freight distribution system causing undue delays and additional costs. For instance, a difference of one point lower in the LPI is related to two to four additional days of port hinterland access and a 25% higher physical inspection rate at customs. This measure indicates the relative ease and efficiency with which products can be moved into and inside a country.

In this part of the paper some results of the survey that was organized by the Word Bank in the 2016 is presented. The methodology used a survey format. Nearly 1,000 logistics professional based in 166 countries took part in the survey. Germany is the most efficient and highest ranked LPI countries (Table 4).

Table 4. Scores of Latvia in different components in the Logistic Performance index in 2016 (developed by the authors based on World Bank data, 2016)

Economy	LPI Rank	LPI Score	Customs Rank (Score)	Infra-structure Rank (Score)	Interna-tional shipment Rank (Score)	Logistic quality and competence Rank (Score)	Tracking and Tracing Rank (Score)	Time-liness Rank (Score)
Germany	1	4.23	2 (4.12)	1 (4.44)	8 (3.86)	1 (4.28)	3 (4.27)	2 (4.45)
Netherlands	4	4.19	3 (4.12)	2 (4.29)	6 (3.94)	3 (4.22)	6 (4.17)	5 (4.41)
Belgium	6	4.11	13 (3.83)	14 (4.05)	3 (4.05)	6 (4.07)	4 (4.22)	6 (4.43)
	…	…						
Norway	22	3.73	20 (3.57)	17 (3.95)	25 (3.62)	24 (3.70)	22 (3.82)	39 (3.77)
	…	…						
Lithuania	29	3.63	28 (3.42)	27 (3.57)	31 (3.49)	30 (3.49)	27 (3.68)	17 (4.14)
Estonia	38	3.36	29 (3.41)	44 (3.18)	56 (3.07)	46 (3.18)	48 (3.25)	20 (4.08)
Latvia	***43***	***3.33***	***45 (3.11)***	***41 (3.24)***	***44 (3.28)***	***37 (3.29)***	***39 (3.42)***	***49 (3.62)***

The Table 5 presents the scores of Latvia in different components in the Logistics Performance Index (LPI) of Latvia since 2007. LPI methodology allows tracking the changes that occur in the logistics processes in each country from year to year. Improving logistics performance index is at the core of the economic growth and competitiveness agenda.

Table 5. Scores of Latvia in different components in the Logistic Performance index 2007-2016 (developed by the authors based on the World Bank, 2016)

Year	Customs Rank (Score)	Infra-structure Rank (Score)	International shipment Rank (Score)	Logistic quality and competence Rank (Score)	Tracking and Tracing Rank (Score)	Time-liness Rank (Score)
2007	58 (2.53)	58 (2.56)	29 (3.31)	48 (2.94)	41 (3.06)	35 (3.69)
2010	40 (2.94)	49 (2.88)	21 (3.38)	46 (2.96)	29 (3.55)	49 (3.72)
2012	56 (2.71)	86 (2.52)	84 (2.72)	93 (2.64)	64 (2.97)	90 (3.08)
2014	35 (3.22)	51 (3.03)	33 (3.38)	42 (3.21)	30 (3.50)	19 (4.06)
2016	45 (3.11)	41 (3.24)	44 (3.28)	37 (3.29)	39 (3.42)	49 (3.62)

The data of Table 5 give an estimate of changes in LPI score compared to the previous period. For Latvia, these changes are evaluated positively that characterizes the improving logistics performance indicators till 2014. The LPI in 2014 highlights that Latvia ranking is the highest in the Baltic States in different elements in the LPI. This is positive result comparing with all previous years.

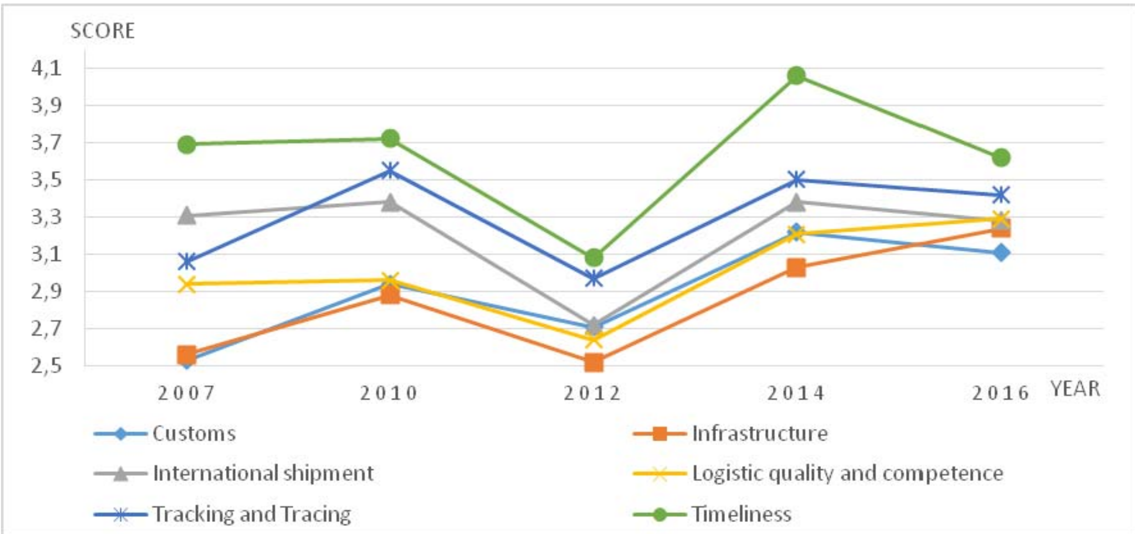

Figure 3. LPI scores of Latvia in 2007, 2010, 2012, 2014, 2016
(developed by the authors based on the World Bank data)

However, the data reported by the Central Statistical Bureau of Latvia shows that in the first quarter of 2016 GDP from transport sector in Latvia decreased to 524290 EUR thousand from 555514 EUR thousand in the fourth quarter of 2015 (Trading economics, 2016). In 2016 Latvia's scores worsened in four elements of the LPI as well as its overall ranking decreased that can also be seen in Figure 3.

5. Transport infrastructure and economic growth

Transport infrastructure is one of the most important parts of economic infrastructure. Transport activity, a key component of economic development and human welfare, is increasing around the world as economies grow. Transportation is a reflection of economic activity, inasmuch as products must be moved to markets (The National Academy Press, 2002). A good transport network is important in sustaining economic success in modern economies (Eddington, 2006). In the developing economies, infrastructure in general and transport infrastructure in particular is seen as an essential prerequisite for economic growth. A number of influential case studies performed by World Bank in India, Pakistan and Brazil (Creightney, 1993; Lall *et al*., 2001) have demonstrated the strong dependency of economic development in these countries upon the quality of transport infrastructure, which unlocks the resources of backwards regions such as land and labour for their efficient utilization (Arts *et al*., 2014). According to American Professor Ishaq Nadiri (1997), who is considered as a pioneer in the study of this question, infrastructure investment "had dramatic impact on the rate of economic growth".

However, analysis of economic literature shows that relationship between transport and the economy is discussion question in both academic and non-academic circles. For example, in the report about transport and economy that has been done for the governance of the United Kingdom (SACTRA, 1997) we can find that, the debate about the transport and the economy is frequently made even less clear by a confusion of terms. The relationship between the two is sometimes taken to embrace different things: transport investments, transport infrastructure, transport improvement, transport traffic, etc. Even the term "economic growth" can mean different things to different people and is often confused with loosely defined discussions of competitiveness (SACTRA, 1997, page 23).

According to the authors of the paper, undoubtedly there is a mutual connection between the quality of transport infrastructure and the macroeconomic performance of the country. Well-developed transport infrastructure gives certain benefits through certain macroeconomic drivers of productivity. These drivers of productivity are improvement of business activity, innovations and investments, labour market, competition, domestic and international trade globally mobile activity, regional economic development, wellbeing of population, environment safety and health.

The interaction between transport infrastructure and economic growth in general can be presented as a simple scheme (Figure 4):

Transport infrastructure development ⟹ Increased number and improved quality of goods and services delivered to the customers ⟹ Growth of GDP/Capita

Figure 4. Transport infrastructure and economic growth

There is undoubtful relevance of the issue of interaction of the transport infrastructure and the economy, since every day governments, businesses, and individuals make many transportation investments and decisions about the use of transport infrastructure. Well-developed transport infrastructure has a direct impact on the quality and cost of logistics services, because infrastructure allows reducing the time and cost of transportation, it decreases risk and improves quality of logistics services by improving the comfort, safety and security.

The debate about transport and the economy takes place against the background of significant trends in both. Figure 5 seek to give some indication of how the Latvian economy and the demand for the passenger and freight transport have changed over time.

Figure 5 shows that the passenger traffic does not present any significant change during the period from 2006 till 2015, it is evident that passenger transport "feel comfortable", regardless of changes in the level of Gross Domestic Product. At the same time development trends of freight, transport does not always correspond to the line changes of GDP. It can be concluded that the role of freight transport as a contribution to GDP has varied over the analyzed period.

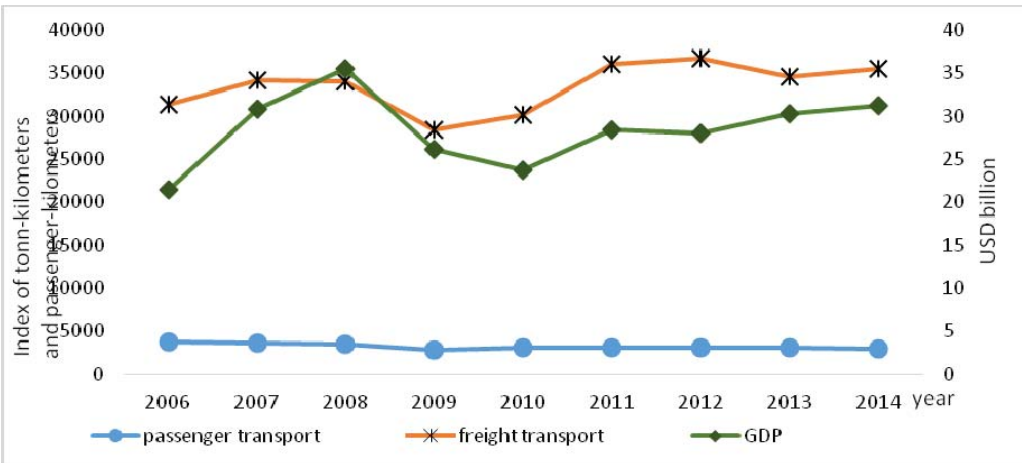

Figure 5. Transport trends against GDP: Latvia 2006-2014
(developed using methodology of SACTRA, Source: Central Statistical Bureau of Latvia)

Therefore, from theoretical point of view, it is possible to conclude that growth in transport at infrastructure corresponds to growth in the economy. However, the relationships between transport infrastructure and the economy are very complex; so, it is very difficult to measure their interrelation. Pioneering work by Ishaq Nadiri, Theofanius Mamuneas from New York University ('Highway capital and productivity growth'), Lakshmanan T.R. ('The Productivity Effects of Highway Infrastructure'), David Aschauer, Alicia Munnell, Dale Jorgenson, and others has significantly contributed to understanding these relationships, "we are far from having an accepted, comprehensive model of the key relationships and how they work (Madric, 1996). Despite the fact that mentioned above article 'Transportation Police Studies, Economic Return from Transportation Investment' was published 20 years ago, it is still on the official web page of the Federal Highway administration of the United States. The above findings confirm the topicality of the investigated question.

6. Conclusions

1. Transport is a priority direction of development of the Latvian economy. Adequate infrastructure is a fundamental precondition for the country transport system.
2. Transportation has substantial direct and indirect effects on economic efficiency and economic growth. Transport infrastructure is critical to sustainable economic growth of the country. Therefore, the analysis of the interaction between transport infrastructure and economy, as well as measurement of the effect of this interaction is a vital issue in the context of implementation of the strategic development plan adopted by the government of Latvia.
3. Approaches based on the calculation of the Global Competitiveness Index (GCI) and the Logistics Performance Index (LPI), applied at the international level, characterize the overall situation in a particular country and in a particular aspect; it is assessed in the context of globalization and allows tracing changes over time. However, the indices GCI and LPI cannot be applied within a country for measuring the productivity effects of transport infrastructure activity and for measuring the return on transport infrastructure investments
4. The analysis of trends in GDP and indicators of development of the transport sector confirmed the existence of relationships between economic growth and transport industry development.
5. Transport infrastructure performance depends on the kinds of performance measurement. The development of the methodology of performance measurement remains significantly important for national economic development. It is necessary to develop the system of measurement and evaluation of general indicators of transport infrastructure and economic growth, that should be measured systematically and that would be generally helpful to all responsible people making transportation-related decisions.

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EVALUATING RIGA TRANSPORT SYSTEM ACCESSIBILITY

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Accessibility can be defined as the facility that helps people to reach a location to perform an activity. Providing a link between transportation and land-use models accessibility can be seen as an indicator to assess transport and land-use policies, especially in urban structures.

The research presents an overview of the case study: the accessibility analysis of the Riga public transport system. The transport system of Riga is presented and highlighted by the public transport services; the problems of public transport system and development plans are discussed. The author continues to analyse the project of the Riga Central Multimodal Public Transportation Hub that is planned in the frame of the Rail Baltica project and provides the analysis of the Riga Transport System accessibility in the current moment, before reconstruction.

Accessibility was calculated on the base of the shortest journey time (or the fastest possible route) during the morning peak hours. The public transport accessibility was analysed and compared with the travel time by private cars. For the calculations, the author used Riga transport model, which is created in EMME software and supported by Riga municipality. The list of zones with the high level of travelling time that needs to be improved for more attractive public transport system was determined.

Keywords: urban transport system, public transport, accessibility, measures

1. Introduction

A sustainable urban transport system (SUTS) requires the strengthening of various features of the system, including accessibility and mobility, reliability and efficiency, as well as safety and security, social equity, convenience and comfort. It should be people- and environmental-friendly. The Urban public transport system (UPTS) should lead to enhanced mobility and generate greater equity between citizen groups. In order to achieve all these aspects, various challenges must be solved and one of the most important is the ability to measure all these features of the system.

As represented in the report of the United Nations Economic Commission for Europe (UNECE, 2015) public transport is a main component of SUTS (Fig. 1).

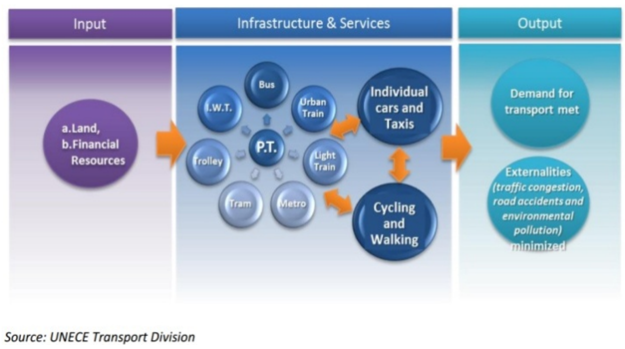


Figure 1. Sustainable urban transport system (UNECE, 2015)

The UPTS is more attractive for commuters and more economically viable for operators if they offer the option to travel from one point of the city to another. In the paper (Yatskiv and Budilovich, 2016) the authors have analysed the main sustainability indicators which are significant for the Riga Transport System (RTS) and on the basis of the questionnaire have concluded that the accessibility is most important for the last one.

Accessibility can be defined as the facility that helps people to reach a location to perform an activity. Providing a link between transportation and land-use models, accessibility can be seen as an indicator to assess transport and land-use policies, especially in urban structures. A definition of accessibility is given by Morris *et al.* (1978). Litman (2012), Geurs and van Wee (2013) provided an overview of literature into 'accessibility' and found different factors that affect accessibility: transportation demand and options, mobility, information, integration of the transport system etc. According to the definition, the level of accessibility depends on the location of activities, quality and quantity of infrastructures, as well as needs of people and companies. The level of accessibility has an impact on the economy because a well-functioning transport system in a combination with the land-use system is a condition for economic development. Accessibility is relevant for the economy, as well as fulfils a social role (van Wee, 2013).

Litman (2012) concluded that there is no single indicator to capture accessibility. In fact, it depends on the goal of the study how the accessibility should be measured. Litman (2015) proposed that sustainable transportation indicators should reflect accessibility-based planning, that tends to consider additional planning objectives (improved mobility for non-drivers, energy conservation, improved safety, etc.) and additional solutions (improving alternative modes, more efficient pricing, more accessible land-use development etc.). Litman (2013) suggested that accessibility-based planning is recognising the following factors that affect accessibility: mobility, the quality of transport options, transport network connectivity and land-use accessibility concerning accessibility-based planning.

The measures of accessibility are diverse and can be person-based, i.e. measuring the opportunities at the individual level or location-based, i.e. measuring the number of opportunities accessible from one location (Geurs and Ritsema van Eck*,* 2001). The person-based accessibility accounts individual factors affecting one's ease of reaching its desired destination, whereas the location-based accessibility presents aggregated measures. The most common measure of the location-based accessibility is the cumulative opportunity measure, that counts the number of opportunities that can be accessed from one location within a given travel time (Geurs and van Wee, 2004). Several authors have written review articles on accessibility measures, focusing on certain perspectives, such as location accessibility (Handy and Niemeier, 1997; etc), individual accessibility (Pirie, 1979; Kwan, 1998), economic benefits of accessibility (Koenig, 1980; Niemeier, 1997) or different perspectives (Geurs and van Wee, 2004).

Van Wee (2013) offered the categorization of the accessibility measures by the following groups:

- Infrastructure-based accessibility measures, analysing the performance or service levels of transport infrastructure, for instance: the length of infrastructure networks, the density of those networks, the level of congestion, and average travel speed on the road network. These accessibility measures are typically used in transport planning.
- Location-based accessibility measures, analysing accessibility at locations, typically on a macro-level and describing the level of accessibility to spatially distributed activities, for example, 'the number of jobs within 30 minutes' travel time from origin locations'.
- Person-based accessibility measures, analysing accessibility at the individual level, such as 'the activities in which an individual can participate at a given time'.
- Utility-based accessibility measures, analysing the (economic) benefits that people derive from access to the spatially distributed activities. This type of measure has its origin in the economic studies.

The attempt to develop public transport (PT) accessibility measures has been discussed in several studies since the 1950s and continues to receive growing attention in the public transport sector (Schoon *et al*., 1999).

The project fulfilled (SUMMA, 2003) stands out among the above measures groups the following ones for PT accessibility:

- Infrastructure-based accessibility measures: level of satisfaction of users of the public transport network;
- Person-based: accessibility of the public transport network, commercial speed of the regional PTS.

Mamun and Lownes (2011) point out the following measures: Service Coverage, Time-of-Day, Waiting Time, Service Frequency, Demographic data, Vehicle Capacity, Route Coverage, Travel Time, Travel Cost, Hours of Service, Walking Route, Access distance, Comfort & parking, Network connectivity, Vehicle Capacity. Alonso *et al.* (2015) represents the density of public transport network as location-based accessibility measure and the quality of public transport as utility-based one.

In many countries and cities the improving accessibility is an important government goal. For the development of the Riga transport system (RTS) exist a large number of documents that have been produced in the past few years and focused on the improvement of traffic and transport situations. These documents have different scopes, purposes and time scales but the visible roadmap for this implementation doesn't exist.

Yatskiv and Budilovich (2016) discussed the new project - Riga Central Multimodal Public Transportation Hub (RCMPT) and provided the procedure for the evaluation of accessibility measures of RTS before and after the planned reconstruction. The aim of this research is to assess and analyse the accessibility of the Riga public transport system (RPTS) itself in general.

The research is structured as follows: in Section 2 the Riga Transport system is presented and highlighted by the public transport services, as well as it contains the discussion on the problems of the public transport system and development plans; the methodology for the accessibility analysis of RPTS is presented in Section 3; Section 4 provides the results of the accessibility assessment of RPTS and theirs discussion; finally, Sections 5 provides conclusions and reflections about the possible implications for the future research.

2. Riga Public Transport System

2.1. Characteristics of the Riga Transport System

Riga, as the capital of Latvia, is a central node of the country transport star-designed network with a total territory of 303,996 km^2 and a population of over 641 007 registered residents by 2015.

The Riga transport system consists of 1778 streets with the total length of 1187.2 km. Streets and roads cover 24.64 km^2 (8%) of the city area by 2015.

Spatially the structure of the population setting of Riga is explicitly concentrated and reflects the city's historical evolution. The spatial structure of the population setting of Riga is made of a core, suburb and periphery, as shown in Figure 2. A railway ring defines the border of the city core, and this part of the city mainly has a compact type of population setting. The suburb is characterised by a combination of micro-districts and mixed population setting. However, as for the periphery, it is distinguished by private houses and few-storey buildings with various recreational territories.

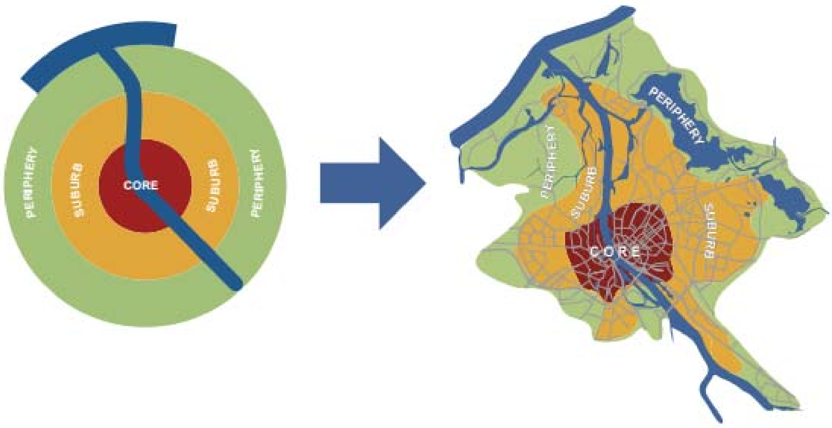


Figure 2. Spatial structure of the population setting of the city
(Source: Riga Sustainable development strategy of Riga until 2030)

Riga agglomeration consists of Riga city and Riga region (7297.6 km^2). Approximately 60% of Riga region residents every day go to work in Riga city, that's why it is necessary to analyse the Riga agglomeration transport system in whole.

Riga UPTS that is represented in Figure 3 consists of 54 bus lines (red routes), 9 tramlines (green routes), 19 trolleybus lines (blue routes), 21 minibus lines (brown routes), passenger railway with 22 stations (black routes), 9 night buses. Railway covers all parts of the city and consists of a large number of passengers and cargo stations. Riga region and Riga city are connected by a number of suburban train lines (from Riga to Jurmala, Saulkrasti, Aizkraukle, Salaspils, Tukums, and Jelgava). Although, it is fully electrified in the Riga city and connects all parts of it but still now the railway passenger services is legally not included to the RUPTS.

The inhabitants' transportation by trams, buses and trolleybuses is provided by the Rigas Satiksme municipal company. The company also provides other services: trips in the Retro tram in summer and bicycle parking (there are more than 30 bicycle parks for about 250 bicycles). The Rigas Satiksme mission is to provide an affordable, reliable and sustainable public transport system, motor transportation and parking services while furthering economic growth and improvement of the quality of life in Riga. (Rigas Satiksme, 2016)

Figure 3 shows public transport network, that it is a very dense in the city centre, and a thinning network towards the borders of the city. The layout of the network is oriented to the centre. The end stations of the routes in the centre are located in five sites and Abrenes street is the major one. There are only 3 tangential lines in the bus network, all in the western part of Riga. Inside the city centre, there are some overlaps between the public transport modes. Outside the city centre the network becomes less coherent and there are missing links in the outer ring of the city on both sides of the Daugava River. The Daugava River is a bottleneck for the development of a complete, coherent public transport network.

Figure 3. Public transport routes (Source: Riga City council)

In general, the coverage of the PT network (walking distances to stop) is evaluated as good or very good. Only 5-7 % of inhabitants of Riga and 3-5 % of employees need more than 5 minutes to reach the nearest PT stop. Comparatively, the north of the old town and the port passenger terminal are served more badly. Moreover, it can be noted that for a city with the size of Riga there are relatively many PT lines. A number of 30 to 40 lines would be more efficient to cover the city and to give 90 % to 95 % of all inhabitants a direct connection to the (historical) city and the central station (Mobility plan, 2011). The review of public transport (PT) mode observations is represented in Table 1.

Table 1. Public transport operations per mode

PT mode	PT mode observation
Tram	• the network covers a part of the city; • all lines have a connection with the city centre and cross the same bridge over the Daugava River; • there is one line that is running from west to east (diametric); • most of the lines have a combined terminal in the periphery of the network; • all tram lines have long walking distances to the central station (200 to 300 meters); • the tram line 2 in the western part of the city to Tapešu iela seems to have no extra function from a coverage viewpoint;
Trolley-bus	• only trolleybuses coming from the western part of the city are running on the Raina Bulvaris (along the city park); • there is an overlap between the trolleybus and tram network, for example, trolleybus line 15 and tram lines 3 and 7 serve the same area;
Bus	• in some cases the existing railway lines make it impossible to create a logical bus routing, due to the lack of crossing possibilities; an example is the quarter Zolitude; • in the eastern part, all major bus lines are combined with tram and/or trolley. In the western part of the city, some arteries are only served by bus; • along some routes the bus is running parallel to the tram and trolleybus lines; an example is a route to Smerlis/Jugla. Furthermore, there are no specific feeder lines.

Main UPTS indicators with statistical information by 2016 are represented in Table 2 (Rigas Satiksme, 2016; Development department, 2016; Wikipedia.org, 2016).

Table 2. Main availability indicators for UPTS of Riga city

Indicator	All	Bus	Trolleybus	Tram
Run (mileage) within the route network (kilometres for tram), in thousand km. (tech run exclusive)	43 513	25 648	10 507	7 357
Route length, in km	1293.81	883	169	99.52
Number of routes	81	53	19	9
Number of vehicles servicing the route, maximum number of hours		344	195	82
Number of passengers carried, m.	146.8	68.66	44.76	33.4

2.2. Priorities for Development of Riga Transport System

The Riga and Pieriga mobility plan in 2011 (Mobility plan, 2011) formulated the main problems related to the traffic and transport infrastructure of the UTS of Riga agglomeration, such as:

- lack of unified planning and management of public transport, road and rail networks;
- lack of the bypasses capacity in the Riga city, lack of bridges between the two sides of the Daugava river and a fragmented street network resulting in traffic flow congestion;
- one of the highest road accidents number in the Europe;
- inefficient transportation businesses;
- lack of pedestrian, cycle and segregated public transport facilities;
- weaknesses in the organizational and legal framework regarding integrated transport systems and promotion of sustainable mobility;
- high level of air pollution etc.

The South Bridge was put into operation in 2012, which weakened the problems of connectivity of left and rights side of the Daugava River banks, but not fundamentally solved the problem.

Riga Municipality actively developed cycling system in 2014 (Kokins, 2014), but this only worsened the problem of traffic jams in Riga.

The main determining the long-term strategy for the development of transport in Riga documents - Sustainable development strategy of Riga until 2025 (Stratēģija 2025, 2005) and Sustainable development strategy of Riga (SDSR) until 2030 (Strategy, 2014), in which one of the main purposes is to improve the UTS.

Perspectives and guidelines of the transport infrastructure are based on a hierarchical system: pedestrian - cyclist - public transport - private transport - freight transport. As defined in SDSR (Strategy, 2014), the key public transport infrastructure element will be the Riga Central Railway Station (RCRS), which will provide multimodal functions. The station needs to be functionally and architectonically connected to the international bus station. The largest bicycle park must be made here in Riga with an opportunity to leave bicycles in safe for the night. Regional park & ride points in Torņakalns and Pētersala (residential areas in Riga) will support the Central Multi-Modal Public Transport Hub.

SDSR proposes the new transport structure, as shown in Figure4 (Strategy, 2014), which defines the main points of the SUTS development, such as:

- free central part of the city of transit transport, therefore simultaneously reduce fragmented nature of the main roads in Riga;
- the necessity to complete the connection of Dienvidu tilts (Southern Bridge) and non-constructed parts of the Eastern main road as soon as possible;
- the Northern Corridor project will reorient freight transit flows;
- the Riga International Airport, Riga Passenger Port, and the entrance of “Rail Baltica” to the RCRS should be mentioned as the transport infrastructure objects of national importance;
- a logical public rail transport connection should be constructed from the RCRS to Riga International Airport.

The priorities are formulated as follows (Strategy, 2014):

- development of traffic infrastructure, reducing the traffic of car transport in the centre of the city and residential territories of localities when guiding the intense traffic to city main roads and motor roads and developing public transport traffic, cycling traffic, and walking;

- priority measures as for traffic safety and the improvement of air quality are making a better situation in the centre of Riga;
- harmonisation of the works with holders of engineering communications prior to reconstruction of a road surface;
- consideration of the aspects of environment availability for a person with functional disorders by implementing projects and providing services;
- optimisation of transport flows to reduce pollution.

Figure 4. Perspective transport spatial structure of the city
(Source: Sustainable development strategy of Riga until 2030)

Moreover, in the SDSR (Strategy, 2014) the main priorities for the Rigas Satiksme are identified:

- renovation, reconstruction, and improvement of the public transport infrastructure, as well as the modernization and renewal of public vehicles in order to comply with optimal servicing times, requirements of customers and legislation provision of the public transport priority in the overall transport system of the city of Riga foreseeing rail transport as a ground for the public transport system;
- optimisation of routes and schedules for better availability;
- improvement of the integrated public transport system;
- improvement of a flexible ticket system according to wishes of the customers and technical opportunities.

The aim of sustainable development of urban transport system is to improve all quality indicators, particularly one of the most important – accessibility. The major problems of accessibility and PT using are that it has no legal platform for the settlement and managing of the passenger transportation, between all the areas of Riga agglomeration. In addition, there is no cooperation of SUTS between the authorities. As described, there is a number of plans for improving the UTS, but there is no the integrated plan for their implementation. For example, for the implementation of the new HUB project to the existing UTS, there is no the comprehensive analysis of it. That’s why it’s necessary to analyse how the new HUB development will improve UTS by passenger railway and regional buses services integration. And also it is necessary to analyse the implementation of all development points that are described above. This research will analyse the accessibility by PT and by car from all zones to one (centre) for the current UTS situation without new HUB constructing.

The accessibility analysis will be created using the methodology from Section 3 based on the existing data.

3. Methodology of Accessibility Assessment for the Riga Public Transport System

For a complete analysis of the accessibility both the data on demand and on supply is needed. But there is no information about demand because the travel survey in Riga agglomeration wasn't done. To analyse the accessibility of the Riga transport system the package for the simulation of traffic flows EMME 4 are used. It is an interactive and graphical multi-functional system for the planning of urban traffic. Information, which is used to model the transport system, consists of two parts:

1. Statistical information used in the form of O-D matrices and PT routes;
2. The geographic information consisting of a network of streets and urban settings.

For the calculations, the author used Riga transport model, which is created in EMME software and supported by Riga municipality. This model uses 180 statistical zones (124 in Riga and 56 across the territory of Latvia) for the urban transport planning.

In addition, the Riga Transport model (RTM) includes demand inputs:

- The structure of the demands (origin-destination demands (O-D survey by 2014) by auto, turn movements, link (speed, road category, traffic counting data by 2014)).
- Time period demand requirements (morning peak hours (from 7 until 10 AM)).
- A number of vehicle classes (car, truck, bus, tram, trolleybus, minibus by 2015).
- Trip purposes (journey to work).
- Network input (network inputs include all inputs on the supply side): the network geometry, intersection attributes etc.

By taking into account the existing information, it was decided to use the location-based accessibility measures and calculate the time impedance. The time impedance involves the shortest path (shortest distance from all zones to centre) and the travelling time. To obtain the result, the transit equilibrium assignment was simulated.

The transit equilibrium assignment based on the notation of optimal strategies (Spiess, 1984; Spiess and Florian, 1989) was used. Travellers choose among a set of attractive lines at a stop, select the alighting node and repeat the choice until they reach the destination.

Before starting the PT assignment, auto assignment was calculated to determine network congestion. An important feature of the EMME assignment tools is that the PT assignments may use data related to the PT network, and the PT assignments may use data that results from the auto assignment:

- The road capacity used by PT vehicles can be taken into account in the auto assignment. This is done by specifying the auto equivalent of PT vehicles as background volumes when preparing the scenario for a PT assignment.
- The dependence of the travel time of PT vehicles on the congestion on the road network can be taken into account in the PT assignments. This is done by using a PT time function which is a function of the auto time.

The two variants were analysed: if traveller uses PT (1 variant) or cars (2 variant).

For PT impedance, modelling the following input data was used:

- PT line routes (in both directions). The used values were presented in Table 3.

Table 3. A number of PT routes

PT mode	Route number
Bus	106
Tram	18
Microbus	46
Trolleybus	38
Summa	208

- Fleet characteristics: PT modes (tram, bus, trolleybus, and microbus) and their attributes. The data of fleet is represented in Table 4.

Table 4. PT vehicle modes and characteristics

Vehicle description	Seated capacity	Total capacity	Number of vehicles of this type
Microbus	19	21	1
Tram	76	336	126
Tram _ one section	38	168	1
Tram _ four section	61	301	1
Trolleybus _ small	31	89	265
Trolleybus _ long	43	170	46
Bus _ mini	21	40	58
Bus _ small	28	102	195
Bus _ average	42	153	1
Bus _long	38	175	175

- A number of vehicles needed to service route and frequency.

Based on the fact that survey data doesn't exist, zero demand was used for the PT assignment modelling. The Extended PT assignment tool from EMME was applied to determine the accessibility and to review the strategies of PT users (e.g., "how many average transfers for a given O-D pair"). With this tool, there were specified a scalar demand matrix that is equal to zero and output the total impedance to a full matrix. This tool should be run after we have performed the extended PT assignment described below, and will store the average number of boarding (i.e., the initial boarding plus the number of transfers) in the matrix specified in the Average-boarding field.

A multimodal, multipath PT assignment that generalizes the Standard PT Assignment (optimal strategies) to allow for the explicit modelling of origin-connector choice, sensitivity to travel time (in addition to headway) for the choice of PT services at common stops, and more. It also provides saving of strategies and sophisticated post-assignment analysis capabilities. According to the strategy, the traveller chooses a set of paths before embarking on the trip and then lets the vehicle that arrives first at a stop to determine which of these paths to take.

The attractive lines are a subset of the lines serving a node that are effective in moving the traveller towards the destination, and the traveller is willing to choose any of them, whichever comes first. On the other hand, the traveller will not consider boarding a line that is not attractive, even if this line comes before an attractive line.

The type of strategy that is considered in EMME can be expressed as follows: at each node where is waiting (PT stop), the traveller chooses a set of attractive lines, takes the first vehicle to arrive from any of these lines, and pass at a predetermined node, based on the expected travel time to the destination; this process is repeated until the traveller reaches his destination. When the network contains auxiliary PT links, these are also considered in the computation of strategies.

A path-based PT analysis involves the computation of an attribute for each path included in the strategy. This path attribute is computed by summarizing one or more trip components along the path using a path operator. A threshold determines which paths are selected. Several analysis results may be saved in matrices or extra attributes.

In an optimal strategy, the ***impedance (travel time)*** to a destination of the PT line determines whether or not the line is attractive. However, only the frequency of attractive lines determines the proportion of flow assigned to each of them.

The extended PT assignment makes it possible to consider both frequency and impedance to the destination, when distributing the flow between the attractive lines at a node. The underlying assumption is that travellers may be willing to wait longer in order to board a faster line.

When determining the attractive lines and their proportions, the lines serving the node are processed in increasing the order of their impedance to the destination. Each time when an attractive line is added to the set, the waiting time at the node and its impedance to the destination, as well as the proportions of all the currently attractive lines, are updated. (Inrosoftware.com, 2016)

The main idea of this research is to analyse the accessibility of PT. That's why, the auto assignment methodology was not discussed. The existing auto assignment data (journey time and traffic flow) was taken to analyse and simulation was not done. The data was taken only for the comparison of the results.

4. Results and Discussions

Riga development strategy until 2025 (Stratēģija 2025, 2005) defined that indicator of average travelling time PT must be not higher than 37 minutes in 2005. But in the future – 30 minutes. Using the above described methodology the PT impedance was calculated and the results were presented in Figure and generalised in Table 5.

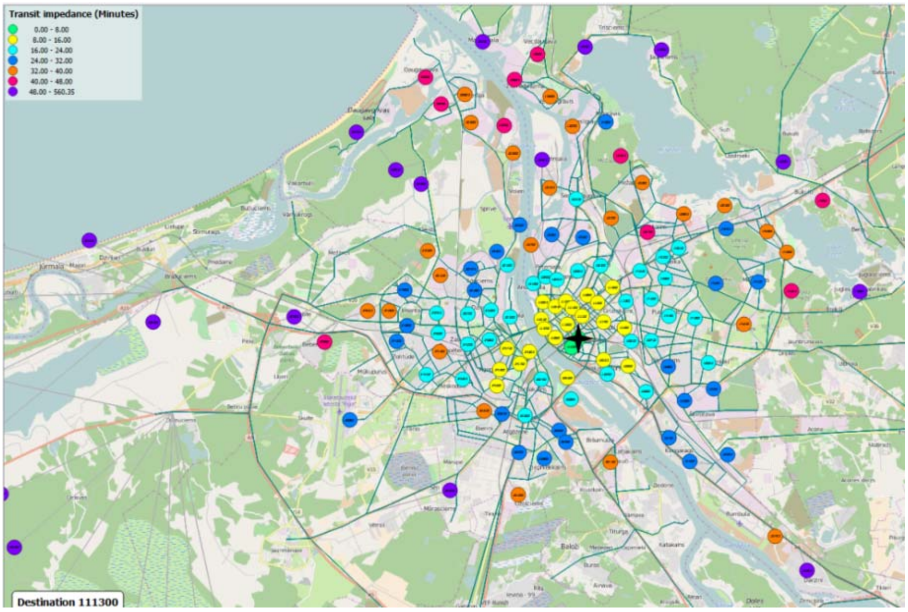


Figure 5. Map showing Riga PT impedance created by EMME in minutes (Source: EMME software): (green: 0-8, yellow: 8-16, light blue: 16-24, blue: 24-32, orange: 32-40, red: 40-48, purple: 48-∞)

The simulation results of the travelling time by car and by public transport from all zones to one are displayed in Figure 5 and Figure 6. Colours in the figures mean intervals from 0 to 48 minutes and distribution shows how long it takes to get from all zones to one, where the new HUB is planned. Circles represent the statistical area (zones) of the city, which are used for the simulation.

Table 5 represents the percentage ratio of the accessibility of public transport.

Table 5. PT modelling results

PT impedance (min)	level	%
0-8	pedestrian	2
8-16	excellent	18
16-24	good	10
24-32	normal	20
32-40	average	19
40-48	bad	8
48----	worst	23

As mentioned, for modelling are used 180 statistical zones (124 in Riga and 56 across the territory of Latvia). Our task is to analyse the accessibility of public transport in Riga, so, the rest of the territory of Latvia was not accounted in this research. Following on from the results of Table 5, it is possible to draw the following conclusions that problems with accessibility of a centre on any mode of PT, according to the accepted standards, exist for 31% of zones. It is necessary to pay attention to 10 zones, which are very remote from the centre and it is needed to improve their accessibility of PT, represented in Table 7 and marked bold. The auto assignment data was taken to compare the time that residents spend to reach the city centre by car. The results of time spent on travelling by car and the distribution elapsed time from all zones to one are represented in Figure 6 and in Table 6.

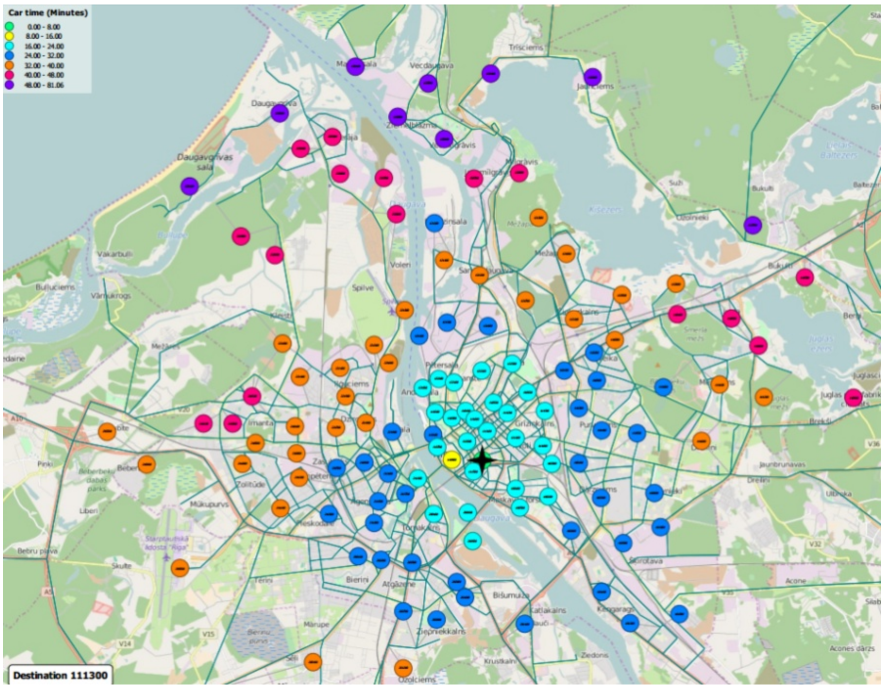


Figure 6. Map showing Riga car impedance created by EMME in minutes (Source: EMME software): (green: 0-8, yellow: 8-16, light blue: 16-24, blue: 24-32, orange: 32-40, red: 40-48, purple: 48-∞)

Table 6. Car modelling results

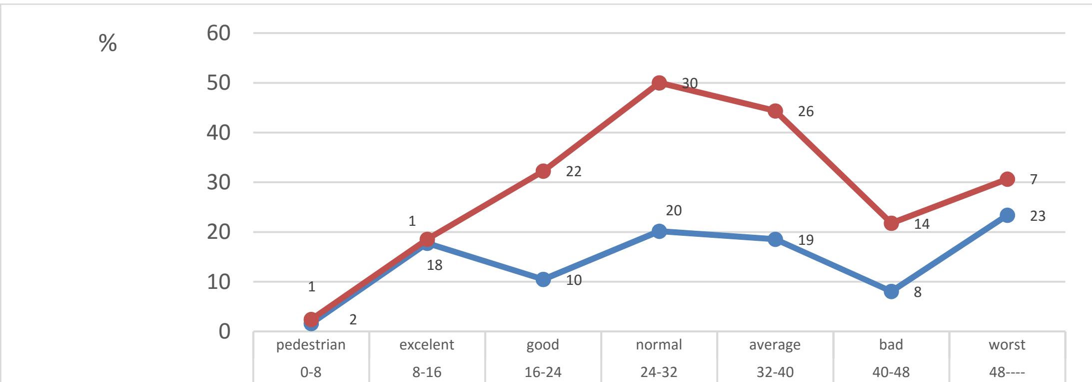
Car impedance (min)	level	%
0-8	pedestrian	1
8-16	excellent	1
16-24	good	22
24-32	normal	30
32-40	average	26
40-48	bad	14
48-----	worst	7

The analysis of the simulation results is presented in Figure 7, which shows the results of Table 5 and Table 6 (the percentage of zones available). The data from the diagram represents that travelling by car is faster than travelling by PT. It means that residents from 31% of zones can reach centre by car in the interval of time between 24 and 32 minutes, but by PT only 20%. Also, the worst results of accessibility are for 23% by PT and only 7% by car of the total number of zones. The number of zones with a high level of travelling time by car is bigger than that of travelling by PT. All zones having the high travelling time are situated in a suburb and in the periphery territories. The simulation results represent that the biggest part of city zones with a low level of accessibility is situated in the core territory.

Table 7 gives the overview of zones with the high level of travelling time that needs to be improved. The table represents PT and Car impedances of zones with “bad” and “worst” results (marked bold in Table 7). Some zones, such as Spilve, Buļļu kāpa, Buļļi, Daugavgrīva, Bolderāja 1, Krievu sala, Berģi, Bukulti, Jaunciems, Trīsciems, Vecāķi, Mangaļsala, Vecdaugava un Vecmīlgrāvis, have a huge accessibility problem both by cars and by PT represented in this table. It means that UTS needs to be deeper analysed to solve this problem of accessibility.

Table 7. Zones with no sufficient time of PT and car impedance

Nr.	Zones with accessibility problem	
	PT impedance	Car impedance
1.	**Bukulti**	**Bukulti**
2.	**Brekši**	Brekši
3.	Bolderāja 1	Bolderāja 1
4.	**Buļļi**	**Buļļi**
5.	**Buļļu kāpa**	Buļļu kāpa
6.	Berģi	Berģi
7.	**Jaunciems**	**Jaunciems**
8.	**Mangaļsala**	**Mangaļsala**
9.	Daugavgrīva	**Daugavgrīva**
10.	**Trīsciems**	**Trīsciems**
11.	**Vecāķi**	**Vecāķi**
12.	Vecdaugava	**Vecdaugava**
13.	Vecmīlgrāvis 1	**Vecmīlgrāvis 1**
14.	Krievu sala	Krievu sala
15.	**Spilve**	Spilve
16.	Beberbeķi	Bolderāja 3
17.	Čiekurkalns	Šmerlis
18.	**Dārziņi**	Jugla 2
19.	Juglas mežs	Vecmīlgrāvis 2
20.	Kundziņsala	Jugla 1
21.	Mežaparks	Jaunmīlgrāvis
22.		Aplokciems
23.		Bolderāja 2
24.		Imanta 1
25.		Imanta 2
26.		Krēmeri
27.		Ķiburga



	pedestrian 0-8	excelent 8-16	good 16-24	normal 24-32	average 32-40	bad 40-48	worst 48----
Car impedance (min)	1	1	22	30	26	14	7
PT impedance (min)	2	18	10	20	19	8	23

Figure 7. Representation of zones accessibility of PT and cars

The results indicate that it is necessary to continue to popularize the movement by PT. For example, to continue developing the policy of various benefits for travel by PT. Also it is necessary to create multi-modal hubs and really introduce the multimodal principles in RTS for passenger convenience and travelling time saving. It is also necessary to create a route that would connect peripheral areas, because now the major part of routes has the routes terminus in the city centre. The demand of passengers must be analysed to other routes. Moreover, it is recommended to continue to implement the planned transport infrastructure and conduct ex-ante holistic analysis of RTS state after its implementation.

5. Conclusions

Accessibility can be defined as the ease with which an individual can reach a location to perform an activity. Public transport accessibility is defined as the quality of PT, serving a particular location and the ease with which travellers can access public transport service. Different scientists conclude that there is no single indicator to capture accessibility and suggest measuring public transport accessibility using a set of indicators based on travel cost, gravity-based, constraints-based, utility-based and composite approaches.

Integration of railway in the city transport system would improve the accessibility and would help promote the use of public transport of the inhabitants of Riga and Riga region. Moreover, it will help to reduce the air pollution.

The accessibility for public transportation comparing with the travel by private cars was assessed and analysed. Accessibility is calculated on the base of the shortest journey time (or the fastest possible route) during the morning peak hours by public transport and by private cars. Then the total number of destinations that could be reached by public transport within a specific (attractive) travel time was determined.

The results of the accessibility analyses demonstrate issues about the development of an integrated roadmap to implement the SUTS involving all stakeholders.

Further research will be focused on finding a solution for improving accessibility including:

- accessibility by PT through building a HUB taking into account the driving directions;
- the wider geographical area to assess accessibility and connections between the Riga city and the key destinations in the surrounding regions.

Using the before-and-after analysis of RTS accessibility helps to identify how HUB needs to be improved or where it is required to promote the public transport network based on the criteria of accessibility measurement.

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MESOSCOPIC SIMULATION FOR AUTOMOTIVE INDUSTRY APPLICATIONS

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The paper deals with the evaluation of the mesoscopic simulation concept on a problem from the automotive industry. Mesoscopic simulation is settled between the well known concepts of microscopic simulation (discrete event simulation) and macroscopic simulation (system dynamics). The mesoscopic method is commonly implemented with the discrete rate simulation paradigm, which combines characteristics of discrete event simulation and system dynamics. As system dynamics, discrete rate simulation is a flow based paradigm dealing with stocks and flows but also event driven like discrete event simulation. Mesoscopic models obtain a higher level of detail compared to macroscopic models as also a lower modelling effort and run time compared to microscopic models. Looking on the automotive industry, it is expected that mesoscopic simulation is beneficial to support decisions on the operational and tactical level of planning, where discrete event models are not appropriate. To evaluate this thesis, a mesoscopic model of a goods inwards department of the BMW company will be created and compared with a corresponding discrete event model from BMW regarding simulation results and run time.

Keywords: Automotive Industry, Logistics Planning, Production Planning, Mesoscopic Simulation, Discrete Rate Simulation

1. Introduction

The usage of simulation in the automotive industry is customary to evaluate and visualize planning results before start of production (Schneider, 2008) (Hab and Wagner, 2010). The discrete event simulation paradigm (also known as microscopic simulation) is mostly used to model systems of production and logistics because of its abilities to illustrate the original system considering a high level of detail and to deal with single flow objects within in the model. Significant disadvantages of discrete event simulation are the great modelling effort as also the comparatively high computational time for simulation (Reggelin, 2011). Thinking about daily decisions after start of production and short-term planning tasks within the operational business, it is questionable if the effort for creating and running a discrete event model is worthwhile or if the time span, until the operational decision have to be settled, is great enough to model and simulate the problem before.

An approach to support also such kind of problems with simulation is the mesoscopic simulation concept, which was developed at the Fraunhofer institution in Magdeburg. Based on the discrete rate simulation paradigm, mesoscopic simulation is settled between discrete event (microscopic) and continuous (macroscopic) simulation. Both the level of detail and the effort for model creation and calculation are less compared to discrete event simulation and higher compared to continuous models (Reggelin, 2011).

One main objective of this study is to identify typical tasks in the automotive industry for which mesoscopic simulation could provide significant advantages in the phase of planning. In the next step the opportunities of mesoscopic method will be evaluated with a simulation study of a real problem from the automotive industry. The problem originates from an assembly plant of the BMW company. A mesoscopic model will be created, which represents the goods inwards department of the assembly plant with all relevant logistics processes. The results of the mesoscopic model will be compared with the results of an already existing discrete event model, to figure out the proximity of the results to the microscopic model, looking also on the modelling effort and the runtime for simulation.

2. Relevant Tasks in the Automotive Industry

A simulation based solution is not for every problem reasonable. Simulation is used to analyse the dynamic behaviour of production or logistics systems. Especially in the planning process of a system simulation has a great relevance, but also in other phases of the system lifecycle simulation offers potentials to support decisions (Reggelin, 2011) (Kuhn and Raabe, 1998). Figure 1 gives an overview about common tasks of simulation.

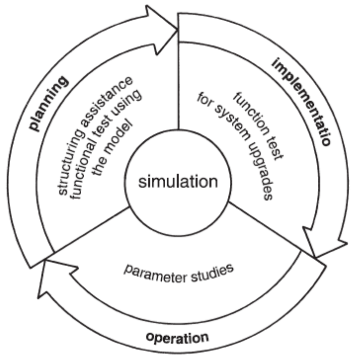

Figure 1. Application fields for simulation (VDI3633, 2010)

Looking on the wide range of production und logistics processes in the automotive industry, it is necessary to define a relevant scope of tasks for which the usage of simulation is relevant. As reported by Schenk (2014), planning tasks can be classified according to their time horizon to fulfil. More precisely, planning tasks are differentiated into operational, tactical and strategical tasks. Operational tasks have a time horizon of less days till a few weeks and are characterised by decisions regarding the day-to-day-business. The tactical planning deals with a period of several months or years and includes for instance procurement, production planning or definition of distribution channels (Kuhn and Hellingrath, 2002). Long-term business decisions with a scope of three years and more are related to the strategic planning level. Relating to the automotive industry, (Schneider, 2008) assign typical tasks before start of production (SOP) to the three levels of planning (strategic, tactical, operational), illustrated in Figure 2.

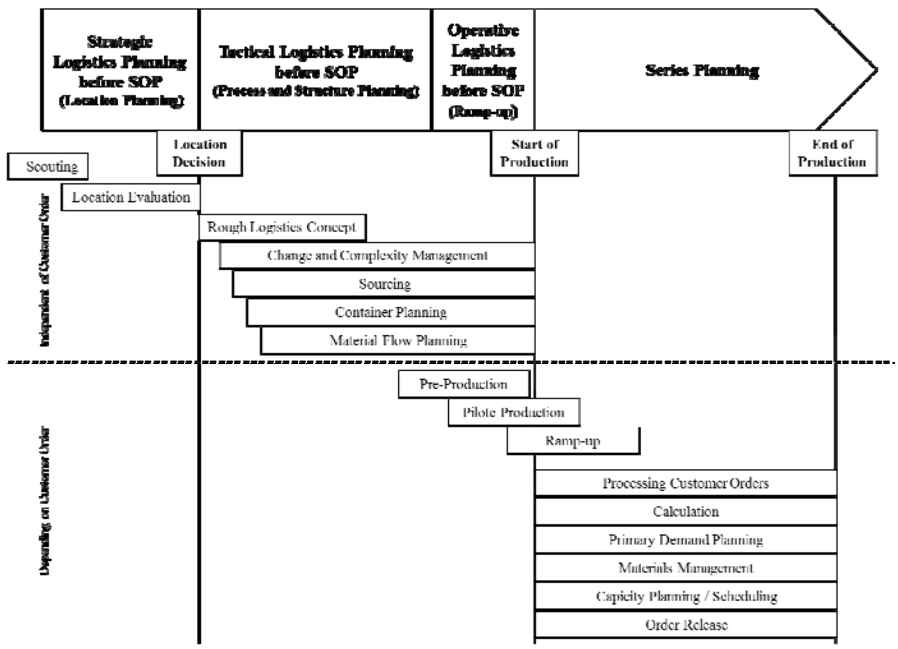

Figure 2. Phases and tasks in the logistics planning from the development phase until End-of-Production (Schneider, 2008)

Regarding the strategic planning, (Schneider, 2008) sees the focus of the logistics in supporting location decisions. Within the tactical planning, the design of processes as also the creation of logistics concepts and packaging concepts are the main tasks. More precisely, the tactical planning includes a rough logistics concept as guideline for more detailed planning. The detailed concept consists of the parts list of the future vehicle, plans of containers and packages, the detailed material flow from the suppliers to the end of the assembly line and the calculated demand of transports, containers, space and staff. Looking on the operational planning, Schneider describes the Ramp-up management as main element in this phase. The logistics department is responsible to ensure the supply of all necessary parts. The target is to improve the logistics processes and the parts supply in relation to the rising production volumes of the assembly line, until the production processes are ready for "Job No. 1" – the first production output, which quality is suitable for customers (Schneider, 2008). Corresponding to Figure 1, all this applications are suitable to support them with simulation analyses.

3. Conventional Modelling Concepts to Simulate Production and Logistics Systems

There are two basic modelling concepts to analyse the structure and behaviour of flow based systems: The microscopic approach, which has to be implemented with the discrete event simulation paradigm, and the macroscopic approach, which should be realised with the system dynamics simulation paradigm (Reggelin, 2011). Both concepts will be shortly described in the following paragraphs.

3.1. Microscopic Simulation Models

Characteristic for the microscopic simulation is the low level of abstraction and aggregation of the real system. Because of the high level of detail, microscopic models are usually used to support operational questions. Microscopic models are generally created with the discrete event paradigm. The name of this paradigm is explained by the behaviour of those models during a simulation run. Changes of variables and system states are triggered in certain (discrete) points of time – more precisely if an event occurs (Banks, 2015). An event is defined as the change of the position of a flow object or as the change of the state of a stationary element (Reggelin, 2011). Like demonstrated in Figure 3, the resulting discrete simulation is defined by impulsive inflows and outflows as also by stepwise changing stocks.

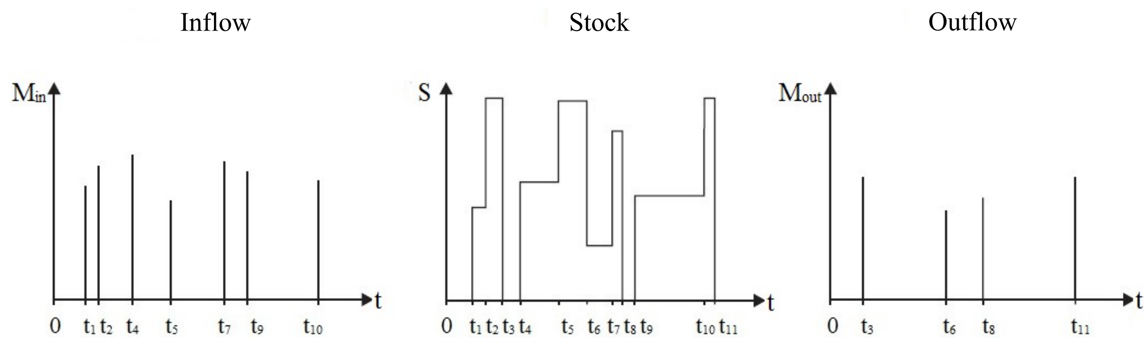

Figure 3. Process model of the discrete event simulation (Reggelin, 2011)

Often events are subject to stochastic influence, which results in the demand for a couple of experiments to get statistical save results. The organisation, processing and evaluation of the several experiments can consume a lot of time and is increasing with the effort for a simulation study (Scholz-Reiter, 2008). The activities and processes, which would be responsible for an event in reality, are unattended in a discrete event model (Page, 1991). Nevertheless is the effort for modelling and computing of discrete event simulation models very fast growing with rising complexity of the real system, caused by the very detailed imitation of the real system and the consideration of every single flow object as model variable (Reggelin, 2011).

3.2. Macroscopic Simulation Models

In contrast to the microscopic approach, the macroscopic simulation is known for its high aggregation of the system to be modelled and therefore the low level of detail, which the simulation model has compared to its original system. The advantages of this approach are a lower effort for modelling and computing. In the industry, macroscopic models are usually preferred to support strategical decisions. The application of system dynamic models is on the macroscopic level a well known standard (Reggelin, 2011). System dynamics describes a continuous and flow based paradigm to simulate the time-dependent behaviour of systems. Continuous means, that the system will be updated to every point of time during a simulation run – the increasing of the simulation time is not depending on the change of the system state (Borshchev and Filippov, 2004). The continuous character of system dynamic models results in a corresponding behaviour of inflows, outflows and stock changes, which is also illustrated in Figure 4.

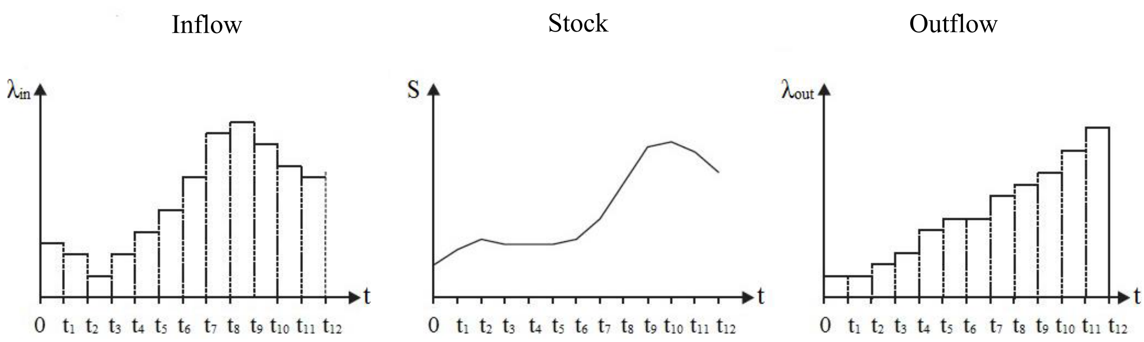

Figure 4. Process model of the continuous simulation (Reggelin, 2011)

The concept of system dynamics is classified as structure theory, which means that this kind of models should only give an idea about the interaction of system elements and their influence on each other. This means also, that system dynamics models are not able to show the structure, function or detailed material flow of a system (Größler, 2007). A system dynamics model is mainly described by stock and flow elements. The stocks represent the current system state. Flow elements have a dynamic character and transfer the content of one stock element to another. The transfer speed is defined by a rate which is recalculated to every point of time by solving a set of differential equations (Wagner, 2004). Although the modelling effort and computational time of macroscopic models is very low, the usage for production and logistics is strong limited: Like already mentioned, the level of aggregation of a macroscopic model is too high to obtain a deeper understanding about a complex system. Typical tasks of the logistics, for instance identifying bottlenecks or calculating the performance boundaries of a system, are in usually not solvable with continuous models. System dynamics model are also in the production and logistics only practical to get a rough idea about the behaviour of a sensitive system (Reggelin, 2011).

4. Mesoscopic Simulation

As described in the previous chapter, the two conventional modelling concepts to analyse production and logistics systems – the microscopic approach (discrete event) and the macroscopic approach (system dynamics) – have several disadvantages, which make their practical usage for some cases questionable. The mesoscopic simulation concept tries to find a compromise between the low computational time as also the high modelling effort of microscopic models and the low level of detail of macroscopic models, which the following figure illustrates.

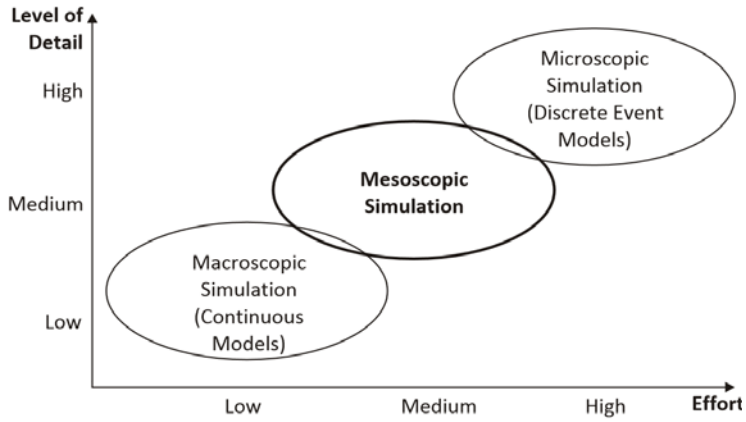

Figure 5. Classification of the mesoscopic approach (Reggelin and Tolujew, 2011)

The concept was developed at the Fraunhofer Institution for Factory Planning and Automation in Magdeburg and was for the first time detailed described by Reggelin in 2011. The main idea of mesoscopic simulation is to program and compute simulation models faster than microscopic models and consider more significant details of the original system than the macroscopic view allows. Usually, mesoscopic models combine two simulation paradigms. The main structure of a system is modelled using the discrete rate simulation paradigm, complemented with discrete event elements (Reggelin, 2011).

Discrete rate simulation is a comparatively new paradigm, which is flow-based as system dynamics but also event-driven as discrete event simulation. The idea arose in 1997 and was introduced by the company Simulation Dynamics. Since the early 2000s further developments were conducted by Imagine That Inc. Nowadays, discrete rate simulation is well implemented in the ExtendSim simulator, which is preferably used to model mesoscopic systems. Discrete rate simulation combines properties of system dynamics and discrete event simulation. One of the fundamental properties of discrete rate is the flow-based characteristic of system dynamics, in which the stocks and flows are used to simulate dynamic systems (Krahl, 2009). However, the system state of a discrete rate model is not changed by integration of differential equations (Sterman, 2000). Instead, the system behaviour is defined by resolving linear equations in different time intervals. This leads to a discrete behaviour of rate based models. Similar to discrete event simulation, the variation of system states in discrete rate models is also event driven (Damiron and Nastasi, 2008).

To explain the mix of discrete rate and discrete event elements in mesoscopic models, an example will be given: If we look on a truck transport, it would be convenient to model this process with the discrete event method, because there are only two states at two points of time: One state is defined as the truck at its start position. The second state is defined as the arrival of the truck at its end position. For the transportation process, it is not necessary to consider all products inside the truck as single entities. Looking on the unloading process after the truck arrived at its destiny, it would be reasonable to model this process in a rate based manner, to give the possibility to analyse states between the points of time, when the truck is full and the truck is empty.

Therefore, the process model of the mesoscopic simulation is the union of the discrete rate and discrete event process model. Inflows and outflows can occur either constant between two points of time or impulsive to single moments. The resulting stock development is either piecewise linear or discrete (Reggelin, 2011).

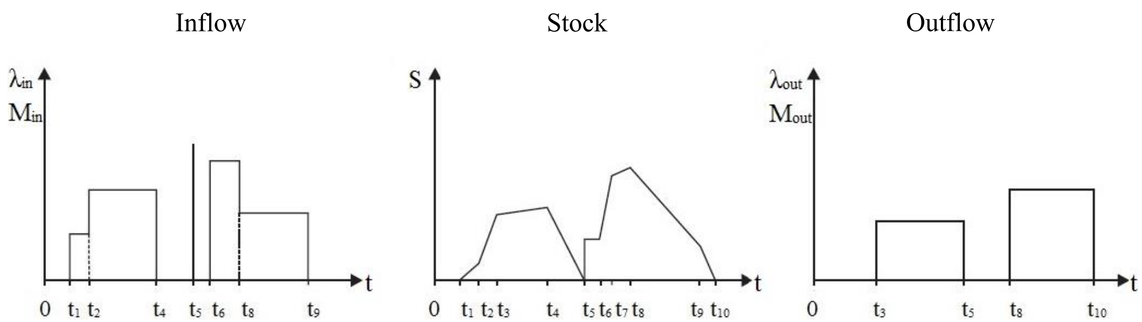

Figure 6. Process model of the mesoscopic simulation (Reggelin, 2011)

Because in most cases mesoscopic simulation does not consider single entities, it seems likely that this modelling concept offers advantages, if the original system has a high emergence of flow objects.

5. Evaluation of the Mesoscopic Approach Based on a Practical Example

As already described in section 1, nearly all planning tasks before production start and operational tasks during the production phase can be supported by simulation. But considering that operational tasks during the production have commonly a short time window to fulfil, it is in most cases not profitable to build a discrete event model, because of the high programming effort and comparatively long run time. System dynamic models are not suitable, because they only help to receive a principle understanding about the behaviour of a dynamic system. The hypotheses is, that the mesoscopic approach is suited for operational tasks during the production, caused by expected lower modelling effort and simulation runtime compared to discrete event simulation and the higher level of detail compared to system dynamics. On a practical example from the automotive industry this hypothesis should be proven.

5.1. System Description

The system to be modelled is a goods inwards department of an assembly plant within the BMW company. Figure 7 illustrates the processes in the system, which is relevant to simulate.

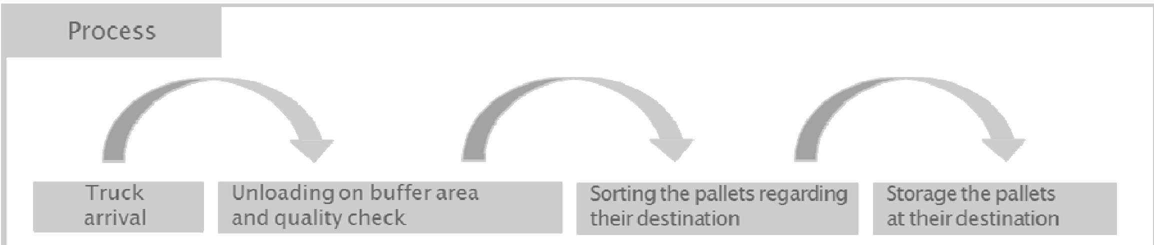

Figure 7. Goods inwards process of a BMW assembly plant

Between 6:00 a.m. and 11:30 p.m., every half hour one till three trucks arrive at the goods inwards department and will get allocated to one of the three unloading gates. The number of pallets on each truck depends on the kind of loaded products. At least a truck has loaded one pallet. At maximum a truck can have 90 pallets loaded.

Before a truck can be unloaded, it passes a preparation process with duration of five minutes. After a truck reach a gate, a forklift with long forks (maximum loading capacity = 9 pallets) unloads the truck. In the real system, there are three forklifts with long forks to unload trucks at the three gates. It is possible that more than one forklift unloads a truck, insofar one or more gates are not blocked by a truck. The complete unloading process depends on the number of pallets in the truck, the number of forklifts which unload the truck, the individual distance between gate and assigned buffer area as also the average driving speed of a forklift (2.79 m/s). Furthermore, for each work cycle the number of pallets on a forklift can vary. It also has to be to consider that forklifts often restack the number of pallets, which they need to transport in the current cycle (probability: 70 %, restack time: 4 s/pallet). The unloaded pallets in the buffer area have to pass a quality check (44 s/pallet), before they get prepared for the next transport (20 s/pallet). When the truck is unloaded, it will release the reserved gate after a delay of five minutes (follow-up process).

After the quality check, the pallets have to be transported to special sort lanes. The pallets are transported by forklifts with short forks (maximum loading capacity = 1 pallet). In the warehouse area are nine of those forklifts in use. The duration of one work cycle to transport a pallet from the buffer area to a sort line depends on the same factors as in the unloading process.

The storage process of the pallets is similar to the sorting process. The main restriction is that pallets have to be stored from the forklifts with short forks. Nevertheless there are nine forklifts with short forks in the system, the storage process can only be initialized, if the buffer areas are empty and all pallets are sorted in the corresponding sort lanes.

5.2. The Mesoscopic Model

The main challenge for the mesoscopic model is to aggregate the several discrete event processes to rates in a reasonable way and to transform the process durations into throughputs. Another challenge is to identify the processes, which still contains a discrete event nature and which therefore are not suitable for a transformation in the discrete rate paradigm. Figure 8 presents the graphical concept of the mesoscopic model.

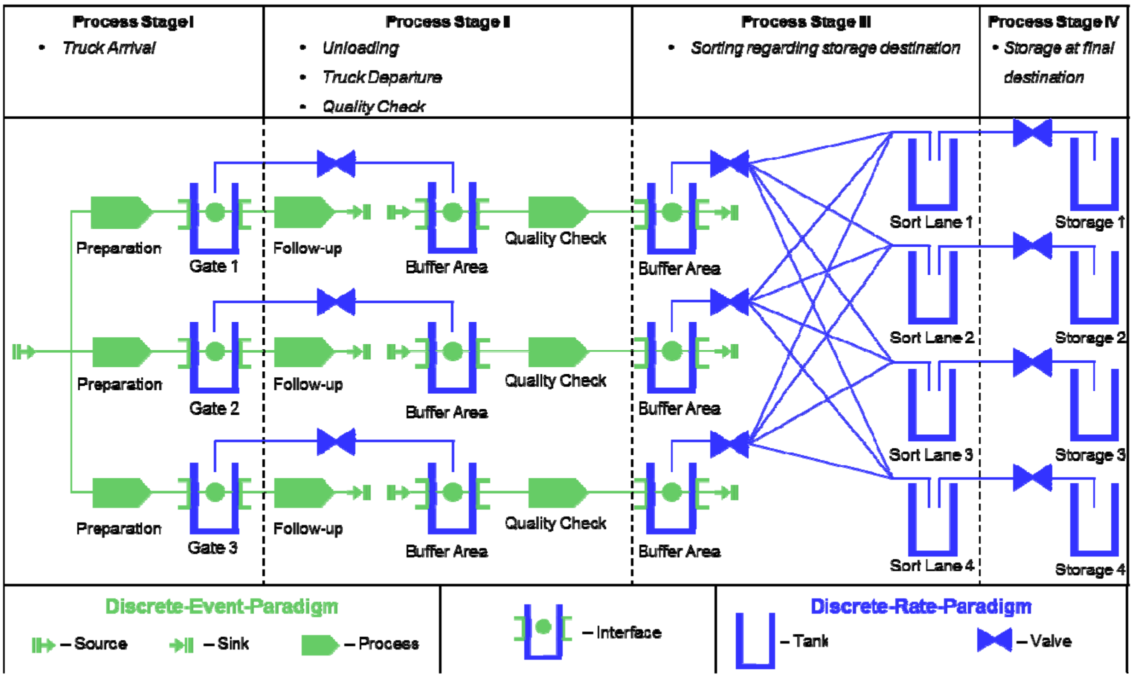

Figure 8. Conception model of the mesoscopic implementation

The created entities in Process Stage I represent arriving trucks in the goods inwards department. Every entity has a attribute, which represents the number of loaded pallets. After passing one of three preparation processes (5 minutes), entities come into the corresponding interface block, which symbolize a gate for unloading. In the gate, the attribute of the entity will be transformed in a discrete rate stock to simulate the unloading process in the next step. The unloading work cycles with a forklift are aggregated to a rate process. The rate is calculated as followed:

$$Unloading\ Rate = \frac{3600\frac{s}{h}}{t_{work\ cycle}} * capacity_{GST} * n_{Gst} \tag{1}$$

whereby $t_{work\ cylcles}$ is the process time for all work cycles to unload one truck, depending on the current number of allocated forklifts for the process, the speed, loading capacity, load and unload time of each forklift, the average stacking time for each pallet as also the distance between gate and buffer zone. $n_{pallets}$ means the number of pallets in the truck. If a truck is unloaded, it passes the follow-up process (5 minutes), before it leaves the system and unblock the gate for following trucks.

For the quality check, the discrete rate stock in the buffer area will be retransformed to an attribute of a discrete event entity. The reason for this is that in the real system a restriction exists, which postulates that pallets of a truck load are only allowed to be sorted, if all of them pass the quality check. Therefore it is possible to save more computational and modelling effort, if only one entity is processed related to its attribute, which contains the current number of pallets (truck load), instead of defining a complex rate equation. The process time for the quality check results out of:

$$t_{Quality\ Check} = \frac{n_{Pallets} * 44s}{3600\frac{s}{h}} \tag{2}$$

whereby the 44 seconds represents the check time for one pallet. After the quality check, the truck load attribute of the entity will be again retransformed in a discrete rate stock. Like the unloading process in the second process stage, the sorting process in the third stage is also characterised by high frequency transports with a low amount of pallets per work cycle. Therefore a change to the discrete rate paradigm is reasonable to aggregate the high number of repeating process steps into one rate. The equation of this rate is quite similar to formula (1), why a detailed explanation is not necessary. The allocation of the material flow to each sort lane is controlled by a empirical distribution.

If all pallets of a truck are distributed on the several sort lanes, the rate, which represents the transport to the final storage destination, is activated. Because of the flow based nature of the mesoscopic model, it is not possible to consider each forklift as single resource object. Instead, a algorithm was written, which allocates the number of forklifts to the single valves as rate parameter. The allocation depends on the total number of forklifts in the system, the needed quantity of forklifts for each process within one stage and the number of forklifts, which every process within one stage would conceded regarding their proportional amount of pallets in relation to the total number of pallets within the process stage.

5.3. Results

To evaluate the mesoscopic model, the runtime for one simulation run (as performance indicator) as also the queue lengths of the trucks in front of the gates and the system throughput per day (as validation indicators) were compared. Table 1 contains the results for each simulation model

Table 1. Comparison of the simulation results from the mesoscopic and microscopic model

Criterion	Measure Unit	Mesoscopic Model	Microscopic Model
Runtime	Minutes	02:10	03:20
Avg. queue length in front of gates	Number of Entities	0,0042455	0,0539707
Max. queue length in front of gates	Number of Entities	3	3
Avg. system throughput	Pallets / Day	3712	3502

The results show, that the runtime of the mesoscopic model is nearly 30 % lower, compared to the microscopic model. Regarding the queue length in front of the gates and the average daily number of pallets flowed through the system, there are perceptible differences in the results. Possible reasons for the variation of the results are different random number generators in each simulator, differences in the allocation and controlling of the forklifts (modelled with variables and a algorithm in the mesoscopic model, instead of single resource flow objects like in the microscopic model) as also probable information gaps about parameters in the microscopic models, which have to be clarify in the next step.

6. Conclusions

The mesoscopic approach is able to obtain a significant lower runtime, even if the aggregation of the real system is relatively low. The described example in this paper to evaluate the mesoscopic approach tried to consider all restrictions of the microscopic model and still achieved a runtime benefit of nearly 30%. Because of the flow based character of the discrete rate paradigm, which was used to implement the mesoscopic model, the control of resources was implemented with variables and algorithms. This approach obtains the possibility to easily change the parameters of resources, because there are no limitations regarding the value ranges of the input parameters, that would disable the functionality of the algorithms. The main disadvantage of the mesoscopic approach is the high modelling effort, which was not expected before this investigation. Due to the low level of aggregation of the underlying discrete event model it is necessary to use a lot of input parameters, stochastic variables and algorithms to precisely model the processes of the microscopic BMW-model. This causes the system to recalculate the rates in a very high frequency, almost making it work a like a continuous simulation model. Nevertheless is the mesoscopic approach a beneficial supplement to the conventional discrete event simulation, to gain quick results for problems from the operational and tactical level.

Acknowledgements

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SOCIO-TECHNICAL INNOVATIONS IN URBAN LOGISTICS: NEW ATTEMPTS FOR A DIFFUSION STRATEGY

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Popular diffusion strategies of technical innovations are so far characterized by a type of linear modelling, following the principles of causal communication chains from the developer to the adopter. From this perspective, neither the consumer nor the technology itself is understood as an actor in the diffusion process. Especially in times in which our understanding of the functioning of social systems increase, we should use this knowledge for the initiation of system change. Diverse environmental, health and economic problems are especially in urban agglomerations of working; living and supply reason enough for implementing a sustainable infrastructure in urban logistics. This paper aims to offer an understanding of technology equally operating with humans in actor networks, which influences our behaviour. So to change our behaviour, we have to start changing our interaction models with technology and offer attractive conditions for more sustainable uses. Thus, the diffusion of an innovation won’t be the question anymore, but the translation of lifestyles into actor networks, like sustainable structures for intermodal interchanges. This paper can be assigned to the area of governance and policy development and should be read as an attempt for the development of systemic implementation strategies in urban logistics.

Keywords: Actor-Network Theory; adoption; e-mobility, innovation diffusion; socio-technical co-evolution; sutainable urban logistics

1. Introduction

According to a current forecast by the Organisation for Economic Cooperation and Development (OECD), two thirds of the world population will live and work in cities and urban agglomerations in the year 2050 (OECD, 2012). Even today, cities produce 80 percent of greenhouse gases and consume three quarters of the world’s energy requirements (Siemens, 2010). By 2050, outdoor air pollution is projected to become the top cause of environmentally related deaths worldwide (OECD, 2012). This trend shows that the increasing urbanisation claims new sustainable mobility concepts for cities to face the negative externalities of current traffic systems by forcing a social change. Actually, environmentally friendly solutions have been developed long time ago, so the history of e-mobility for example already began in 1881 (Bundesverband eMobilität e.V., 2016). But after a short period of prosperity combustion engines gained popularity because of assembly line production, longer ranges and the introduction of electrical drives. Against the background of an increasingly propagated ecological awareness in the 21st century, e-mobility found his way - at least in Europe - to the political agenda back again. So the German Government i.e. aims to bring one million electric cars onto the road by 2020 (Bundesregierung, 2016). But despite this ambitious governmental targets and the long-standing technical development of sustainable innovations in the area of traffic systems, electric cars and cargo bikes do lack of diffusion and thus the market share in Germany remains minimal (KBA, 2015). Obviously the lack of technological know-how or ecological awareness doesn’t seem to be the problem – it might be the lack of implementation strategies and contextual social awareness.

Still the common sense is to consider technological artefacts as something separate and independent from the social context. As the social sciences normally exclude technology from their scientific field, the engineering sciences are used to exclude the social belongings. Defacto both approaches are inseparably linked with each other, as every technological innovation implicates social conditions and consequences, which therefore have already to be considered in the process of technological development. As follows, designing technology means designing society. A systemic approach on the interface of engineering and human sciences, on civil society, economics and politics is needed to work out co-evolutionary strategies between humans and technological artefacts for the extension of technological acceptance.

The scientific contribution of this paper is the strengthening of logistics in its character as a cross-sectional science, especially by focusing its normative part. Lying crosswise to engineering, economic and social sciences as well as to mathematics and informatics, logistics is at least theoretically virtually predestined for translation processes between technical innovations and social needs. The "peek behind the scenes" of social systems that logistics practices by analyzing and modelling material and information flows, reveals what the science theorist Bruno Latour means by the expression: "Humans are no longer amongst its peers" (Latour, 2000).

On the theoretical background of the Actor-Network Theory of the sociologists Bruno Latour and Michel Callon (2) and with the help of the design model of Knut Borrmann an integrative urban intermodal transportation system will be presented hereinafter as one possible systemic approach for a diffusion strategy of sustainable technological innovations (3). This approach can be understood as a theoretical basis for economic, political and private decision-makers.

2. Theoretical Background: The Actor-Network Theory

The Actor-Network Theory (ANT) of (Latour, 1996) sets the theoretical frame of a socio-technical consideration of technical innovations in urban logistics to elaborate adequate implementation strategies. The ANT is a sociological approach, which arose at the interface of engineering and social sciences itself (Latour, 2005) and therefore understands technological artefacts as nonhuman actors, building up networks with human actors. Thus, it follows a different line to conventional, linear diffusion and life cycle models, like the theory diffusion of innovations (Rogers, 2003), which describes the process of social innovation adoption by individuals and social systems by giving an empirically scrutinized review of the target groups to be addressed in the right chronological order to achieve a successful adoption process. In the understanding of Latour instead, innovation diffusion starts with technology development, which turns into a task of networking by procedural connecting heterogeneous entities. In the present case the electric car can be understood as an actor network, whose components "are the electrons, which effortlessly jump between the electrodes; consumers, who give up the status symbol of the motor car and who are willing to invest in public transport; the Ministry for quality of life, which adopts regulations about acceptable noise levels; [an automobile manufacturer], which accepts the fact that he is one of the manufacturers of car bodies; lead-acid batteries, which efficiency has improved, and a post-industrial society, which is on its way" (Callon, 2006). For a stable construction of actor networks, translators for the indispensable translation between the entities are necessary. For the translation task logistics, understood as process sciences, is foreseen. This makes sense inasmuch as every time when a human actor encounters an obstacle and gets interrupted in the execution of his planned action it appears obvious to include other actors, among them nonhuman actors, to solve the situation and to keep the processes going. That means within a system network, formation constantly takes place and produces new programs of action. By the mediation actions of technology, conditions get transformed. Latour presents four different meanings of technical mediation: *Goal Translation*, *Composition*, *Reversible Blackboxing* and *Delegation*. In the following all of them will be shortly described.

The first meaning of technical mediation *Goal Translation* according to Latour, describes how a third actor emerges from a fusion of a human and a nonhuman actor, that from this moment on gets the opportunity to pursue another – a third – goal, that is different from the two original goals of both actors.

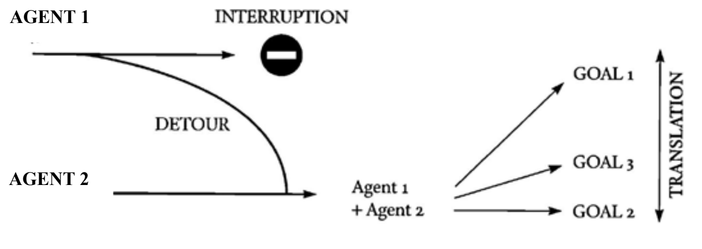

Figure 1. First meaning of mediation: Goal Translation

By the example of a gun "you only wanted to injure but, with a gun now in your hand, you want to kill" (Latour, 1999) illustrates what he means by the arising of a third goal out of the human-non-human composition. Latour uses the word "translation" to mean "displacement, drift, invention, mediation, the creation of a link that did not exist before and that to some degree modifies the original two. […] This translation is wholly symmetrical. You are different with a gun in your hand; the gun is different with you holding it. You are another subject because you hold the gun; the gun is another object because it has entered into a relationship with you" (Latour, 1999).

The second meaning of technical mediation *Composition* clarifies the fact that action is simply not a property of humans but of an association of actants. For example, "flying is a property of the whole association of entities that includes airports and planes, launch pads and ticket counters" (Latour, 1999).

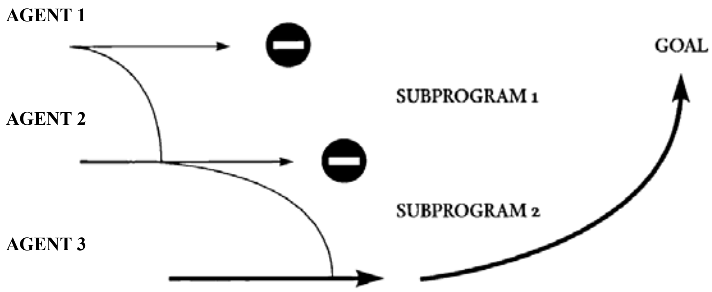

Figure 2. Second meaning of mediation: Composition

If the number of subprograms is increased, then the composite goal – here the thick curved line – becomes the common achievement of each of the agent, involved in the process of successive translation.

Because, as shown in Figure 2, when one agent tries to reach a particular goal the situation often requires a detour by involving others (humans or nonhumans), who bring their own subprograms with them. What is essential here is the composition of action marked by the lines that get longer at each step in Figure 2. The action is performed by Agent 1 plus Agent 2 plus Agent 3. This allows the conclusion, that "action is a property of associated entities. Agent 1 is allowed, authorized, enabled, afforded by the others" (Latour, 1999). By the connection of action programs networks get established.

The third meaning of technical mediation is *Reversible Blackboxing*. This meaning focusses the subprograms of the nonhuman actants, which mostly remain unnoticed. In public attention nonhuman actors usually just begin to exist, when they break down and interrupt the human action. In the process of repair it gets discovered, that a single nonhuman actant consists of further components, which appear as actants within the actor-network themselves. A shift has occurred between actor and mediator. The first two mediations showed that goals are redefined by associations of nonhuman actants, and that action is a property of the whole association, not only of those actants called human. However, as this characterisation shows, the situation is even more confused, since the number of actants varies from step to step by changing the level of consideration (Latour, 1999).

The fourth and according to Latour most important, meaning of technical mediation is *Delegation*. In this context the notion of detour, of translation, should be modified to absorb, not only a shift in the definition of goals and functions, but also a change in the very matter of expression. The action program of a human actor is to be delegated to a nonhuman actor, for example in form of a speed bump, that brings car driver to slow down instead of using traffic signs, that can be ignored or to engage policemen. Not only has one meaning, in the example of the speed bump, been displaced into another, but an action (the enforcement of the speed law) has been translated into another kind of expression, as shown in Figure 3.

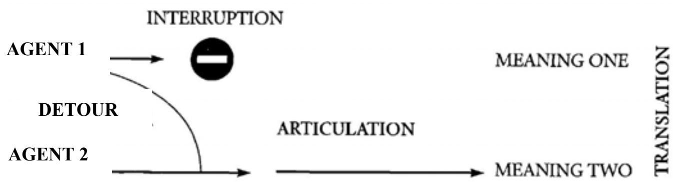

Figure 3. Fourth meaning of mediation: Delegation

Thus, a speed bump is ultimately not made of matter; it is full of engineers and chancellors and lawmakers, commingling their wills and their story together with those of gravel, concrete, paint, and standard calculations.

In summary, it can be said that we live in collectives of human and nonhuman actors, not in human societies as usually assumed. Against the background of the mentioned four meanings of mediation, strategies can be derived for the design of new actor networks in the field of sustainable urban logistics.

3. A development attempt for a systemic diffusion strategy by the example of urban intermodal transport systems

Without consideration of contextual factors neither the functionality of an innovative technology nor the receptivity of the market can be assumed. Because one of the paradoxes of innovation processes is, that the markets, on which new products or procedures shall prove themselves usually don't even exist at the time when strategic decisions must be made. (Lang and Sauer, 1997). With Latour this would mean to give up the notion of introducing a single product, understood as an independent object, to the market, but actively shape the system change that accompanies the product launch. From this point of view hypothetically anticipated futures have to flow in the process of planning and development to allow them to become reality (Herbold *et al*., 1991). The implication of feedback loops does not only change the product itself, but also the context of it. Therefore, it is necessary for involving innovation on a systematic basis to anticipate occurring interaction and modes of action regarding a change of the existing system (Latour, 1983). Offering a natural opportunity to do so, an exemplary model of possible changes within the system, resulting from its dynamics, is crucial. This also enables the user to familiarise with the performance of the operation and to estimate whether the prospective change is to be taken into further stages or be discarded. In this paper, a specific structure of design (Borrmann, 2014) is being used. It firstly analyses the regarded sequence of reality, then brings in needed changes within an autonomous observation and lastly merging the initial system with the strategy developed. Thus shall be shown in an abbreviated example on sustainable transporting options within city logistics. Throughout the main aim is developing a strategic approach, furthermore defining methodical appliances for providing a full performance of a proposal of implementation.

3.1. First step: analysis of the present mobility system

With the ANT it was shown that networking starts where problems arise and detours have to be made. Problematisation is the first step of translation, because according to Latour every action wants to solve a problem (Belliger and Krieger, 2006). As mentioned in the first capture, the fact that an increasingly number of people has come to live in urban areas and the demands on an attractive urban environment increase is one of the problems urban logistics have to deal with. This tendency results in a bad image of urban logistics in the public attention, as it growingly perceived as disturbing activity for passenger transport and the citizens' quality of life. In addition freight traffic in urban areas has several negative impacts on the environment, including CO_2 emissions, use of non-renewable fuels, waste and loss of ecosystems, on public health in form of accidents, noise and air pollution and on the economy by the waste of resources and agglomeration resulting in decreasing journey reliability and city accessibility (Quak, 2007). "However, the urban environment characterised by scarcity of access, i.e., congested roads, space constraints and limitations of infrastructure restricts the efficiency and quality of urban logistics operations" (Hesse and Rodrigue, 2004). For solving the mentioned problems, according to Latour, we have to design a detour. But before this step is taken, which is the focus of 3.2, the suggested method of analysing a situation for problem formulation shall be presented.

In accordance with the design model of (Borrmann, 2014) the first step is to analyse the regarded sequence of reality, which is affected of some noticed problems. The suggested method of system analysis in this paper emerges from the combination of Latours mediation models and the design model with its concept of structural linkage developed by Borrmann. Therefore at first it is necessary to exactly determine the system to be considered. In this case it is much simplified the urban transport system. Therefore out of the four meanings of mediation the following questions could be asked to demonstrate the way of uncovering the positions, where an intervention can be conducted. As it is the uncovering of the black box, which takes centre stage, the third meaning of mediation *Reversible Blackboxing* won't be listed as an extra point below.

- **Goal Translation**: Which goals human actors pursue in the field of urban mobility? Which difficulties come across? Where exactly and under which circumstances in the urban space this difficulties arise? In which ways the problems are normally approached and solved? By the inclusion of which nonhuman actants the arising problems are normally solved? Which goals are inscribed in urban vehicles? Which further goals emerged from the exemplarily fusion of human actors and urban vehicles? Which action processes are where and when in the mobility system of the city typical?

- **Composition**: In which heterogeneous collective the urban vehicles are included? Which lobbyists strengthen the diffusion of non-environmentally friendly urban vehicles? Which factors do automobile manufacturers exclude in their manufacturing processes?
- **Delegation**: Which construction measures in the urban space advantage the spread of non- environmentally friendly urban vehicles?

By answering these questions a holistic picture of the present mobility system can be drawn. For data collection the use of qualitative and quantitative data collection methods is advisable. After the complex structure of the present mobility system is exploited, the design of the new system can be developed.

3.2. Second step: design of a new mobility system

Previous analyses (Borrmann, 2014) have shown that the mobility system as a whole relatively slowly reacts on changes and thus its related effects highly likely make themselves felt after some delay. For the planning of intervention this means that every change must be observed over a longer period in order to assess its efficiency. As another result, (Borrmann, 2014) mentioned a relatively stable steady state, which the mobility systems strives over time. Actually this is a normal property of lasting systems, which are embedded in social systems, according to (Luhmann, 1997), understood as communication systems. Whenever initiated communication processes start grasping themselves, a system gets going and keeps running in an autopoietic way (Luhmann, 1997). The autopoietic dynamic inevitably leads to stable states, as long as the communication keeps going. This is the case in long grown systems, like the mobility system, which is operationally interconnected with several self-contained functional systems (i.e. economic, political, legal and education system) of the society, although it is questionable if the mobility system itself is an autopoietic system following his on logic or more likely an open complex network. The approach adopted in this paper is the understanding of the mobility system as an actor network operationally linking the mentioned functional systems together. That's why neither a traffic system nor a technological artefact can be developed regardless of the system logics of social systems.

Therefore out of the four meanings of mediation following questions could serve as key questions for a first attempt to defining a new traffic system, understood as an actor network, with a cargo bike as the main actor in the network.

- **Goal Translation**: Which goals a human actor has in the field of urban mobility? Which difficulties might come across? Where exactly in the urban space these difficulties might arise? Which goals are inscribed in a cargo bike? Which further goals may emerge from the fusion of a human actor and a cargo bike?
- **Composition**: In which collective the cargo bike is or should be included? Which political, economic, legal and educational actors should be linked with each other around the cargo bike in which way to achieve with the use of the cargo bike a visible increase of new possibilities in urban mobility? How to make the involved actors willing to take the assigned role in the network?
- **Reversible Blackboxing**: Out of which various components a cargo bike should be built up to meet the various requirements initially defined under point "Goal Translation"?
- **Delegation**: Which action programs of human actors in the field of sustainable urban mobility could be delegated to nonhuman actors? Which construction measures in the urban space can be carried out to push the use of cargo bikes, by making them attractive?

Designing an actor (i.e. a cargo bike), means designing a network and designing a network in recourse to the relevant factors of social systems, means the co-production of society and things. After the design of a new mobility system, (Borrmann, 2014) suggests the synthesis of the present and the new system in the next step.

3.3. Third step: Synthesis of the present and the new mobility system

After the system description and analysis of mobility and the design idea are completed, in the frame of structural interconnectedness the synthesis of both systems can be conducted. Thus, the last step in the design model of (Borrmann, 2014) illustrates the whole process of change. For the synthesis of both systems the definition of interfaces is needed. The contribution of this paper is not to find the particular variables in the present mobility system, which can be changed through the combination with new sustainable technology actors, nevertheless it already can be anticipated how a combined structure may look like. The suggestion is in terms of an urban sustainable intermodal transport system. The idea is to assign roles for the different vehicles according to their action programmes and in accordance with the analysed needs in the specific urban area. It is not the aim to completely replace fuel driven vehicles, but to limit their field of action on that areas, where their use definitely makes sense. In the suggested solution model fuel driven vehicles get embedded in a cooperative network of e- and non-e-mobility.

Therefore, again following questions along the meanings of mediation, defined by Latour, could serve as key questions for a first attempt to defining an urban sustainable intermodal transport system, understood as an synthesis out of the given mobility system and the designed cargo bike network. As all relations of relevant heterogeneous entities are functionalised in the black boxes of the networks, the task of this step is to configure a functioning black box for stabilising the new system from the beginning. “If networks become actors and actors become networks, the translation process has to aim the functioning of an actor in a network, by fixing his roles, making his actions irreversible, in summary: constructing black boxes” (Belliger and Krieger, 2006). Thus, after the uncovering of the black box in the present mobility system took centre stage during the analysis phase, at this stage it is the design of the black box the focus is lying on.

- **Goal Translation**: In accordance to the analysis, which locations in the urban space has shown problems in interaction with fuel driven vehicles, which could be solved by the action programs of cargo bikes? And which places are suitable for the strategic positioning of cargo bikes, according to the results of the design phase? Which locations have proven to be capable for urban logistic hubs to load freight units on i.e. cargo bikes? How the advantages of the individual vehicles can be linked to increase the number of possible action programs in urban space?
- **Composition**: Which additional actants, like bike sharing stations at identified stops, can be included in the network, to reduce motor traffic in cities? How the different urban vehicles can be linked with each other in the best way? How many cargo bikes and i.e. electric cars with which facilities are required in urban space to provide urban logistics? Are concepts of accompanied or not accompanied combined transports under the particular circumstances useful?
- **Delegation**: Which constructional renewals are necessary to enable the establishment of an environmentally friendly intermodal transport interchange?

The last step has shown, that it is not only the technical development of innovations, which is relevant, but also the respective action opportunities manifesting themselves against the background of the given mobility system. Thereby it is not the aim to force moral behaviour by implementing environmentally friendly technologies in urban logistics, but to increase the possibilities for action and establish smart forms of cooperation.

4. Conclusion

The aim of this paper was to present a new approach of a diffusion strategy in urban logistics to sensitise decision-makers in the areas of governance, policy and economics for the evolutionary process of humans and technology as a co-evolutionary process resulting in formations of actor networks. Thus the successful diffusion of sustainable innovations in urban logistics, which is currently so important, can’t be seen as the economical spread of technological artefacts anymore, but as a translation of an actor into a network and the translation of a network into an actor. To illustrate what is meant by that perspective and how it can be used in the area of urban logistics, a methodical approach was elaborated, which combines the design model of Borrmann with the actor-network theory of Latour as one possible way of system change in terms of structural interconnectedness. Because the synthesis of given and future systems is decisive, the need of diffusion turns into the need of networking.

The advantages of that method are

- to produce technological innovations already with the social receptivity and in consideration of the current circumstances, by the involvement of relevant actors from different social systems,
- the gain of a multilevel analysis on the micro- (Reversible Blackboxing), meso- (Goal Translation) and macro-level (Composition),

- an early detection of failures in logistic planning phases on the basis of the four meanings of mediation,
- the possibility to analyse, design and combine given and new systems within one model,
- a sustainable intermodal transport system as a suitable implementation design for new mobility systems,
- the extension of logistic sciences with detour modelling and network building,
- the providing of a theoretical background for logistic urban planning,
- a better understanding of human-non-human interaction,
- the theoretical basis for the further development of self-organised technologies in urban logistics.

Since this approach is only a first attempt in thinking about smarter concepts of urban logistics at the interface of social and engineering sciences, the method must be further developed and tested in practical applications. Furthermore the question how logistics can specifically manage the translation between actants and actors, thus how it creates the drifts leading to socio-technical co-evolutionary processes, still remains unanswered. Also the co-evolutionary processes themselves could be tracked historically in a next scientific paper to single out how vehicles and humans influenced each other's development. One of the most interesting scientific topics for further application of this approach is industry 4.0 relating to self-organised machines, interacting as a network within a network by the help of sensor equipment.

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SIMULATION TECHNIQUES FOR EVALUATING SMART LOGISTICS SOLUTIONS FOR SUSTAINABLE URBAN DISTRIBUTION

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Smart logistics solutions have been developed in order to alleviate the adverse impacts of increasing goods' transport in urban areas. However, the effectiveness of these measures can be questioned, if negative impacts during or after solutions' implementation are not considered. Simulation has been proved as valuable tool to evaluate such solutions in advance and support the decision making process. This study contributes in presenting the current state of practice in modelling smart logistics solutions, provides a roadmap in simulation techniques for urban freight transport solutions and improves the knowledge around the patterns currently followed.

Keywords: City logistics measures; simulation; goods distribution; evaluation

1. Introduction

Urban distribution of goods is a main component of sustainable transport networks and one of the key factors to cities' problems on traffic congestion and environmental pollution. The ever growing demand in transport of goods renders the upkeep of a high traffic and living quality in cities, a challenging process. Urbanization, consumerism, technological blooming and international competition cause a vast demand of products and services and make the distribution of goods within urban areas an essential priority for public authorities.

Over the last decades, many smart logistics solutions have been developed to allay cities' problems related to distribution of goods. These solutions complement conventional Urban Freight Transport (UFT) measures and policies, or replace them entirely. However, new approaches are always generated towards those smart solutions, rendering their implementation dreaded in terms of adequacy and sufficiency, due to the lack of past experience. Especially in a multi-dimensional environment as the urban environment, in combination with the multivariate nature of logistics measures, their implementation can bring adverse effects if all aspects are not considered carefully. To avoid such situations, modelling of the proposed measures-solutions is advised, since it facilitates their quantification and consequently evaluation.

Several models, grouped mainly according to the scope they serve, have been applied to evaluate logistics measures. For example, Ambrosini *et al*. (2004) address two families of urban freight models: (a) the *operational* models for improving the flow management and (b) the *systematic* models for evaluating the impact of interventions made in a logistic system. Hicks (1999) under a different approach, grouped the models based on their utility into: (a) *simulation models*, (b) *optimisation models* and (c) *simulation - optimisation models*. Accordingly, Taniguchi's *et al*. (2012) models' clustering was: (a) *optimisation models* and (b) *simulation models*. Optimisation models are associated with the process of finding the best solution out of the number of alternatives the user has in his disposal, based on the objectives need to be achieved. Such optimization models have been used into the logistics field to address issues like sourcing decisions – minimization of total costs (Farahani and Elahipanah, 2008), risk management – come up with strategies to minimize potential disruption (Gaonkar and Viswanadham, 2004), network design – determine the best network for efficient deliveries (Melo *et al*., 2009) and other. Simulation models have as a purpose to replicate adequately a working system in order to understand it better. Then, an adequately calibrated and validated model can be used as a test bed, where different scenarios and optimisation can be tried on. Simulation models, frequently substitute optimisation models, since they can act as fancy manual calculators to test different scenarios and identify the best one, through the trial-and-error process.

The analysis of this paper focuses on simulation models. These models can be derived from the following three simulation techniques: (a) *Systems dynamics*, (b) *Multi-agent systems*, (c) *Traffic simulation* (Taniguchi *et al*., 2012). In research, several simulation models can be found that aim at the evaluation of the impacts of the concerned logistics solution in some or all four principal sustainability impact areas (economy, environment, transport, society) (Anderson *et al*., 2005; UK Round Table on Sustainable Development, 1996; Behrends, 2011). Stakeholders, depending on the category they belong (see chapter 2.1), will be able to see which simulation technique has been applied for the evaluation of a logistics solution based on past experience and other studies.

1.1. Systems dynamics

Systems Dynamics (SD) is a computer-aided approach developed by Jay W. Forrester at MIT University during the 1950's. This approach aims to analyse and solve complex problems related to policy analysis and design by applying feedback control theory to simulation models of organisations (Forrester, 2003; Angehofer and Angelides, 2000). Forrester (1969) in his publication on Urban Dynamics, proposed a new approach for analysing urban related problems, which lays the fundamental grounding for the linkage of the urban dynamics with the decision-making process of urban areas. This approach was widely adopted in the following years, since many applications took place ever since in the area of logistics. Qui *et al*. (2015) describe a systems dynamic model for simulating the logistics demand dynamics in the city of Beijing, China. Teimoury *et al*. (2013) develop a SD simulation model to study the relationships and behaviours developed in the supply chain of perishable fruits and vegetables in Tehran, Iran, as well as to analyse the supply, demand and price interactions. Tako and Robinson (2012) reviewed the Discrete Event Simulation (DES) compared to SD as decision support tools and highlighted advantages and disadvantages in applied case studies. Poles (2013) model a production and inventory system for remanufacturing activities. Shouping *et al*. (2015) developed an SD model to evaluate the logistics system in the city of Guangzhou. Rasjidin *et al*. (2012) examined the aspect of weather conditions and energy supply's fluctuation in respect to minimization of energy retailer's cost.

SD is an integrated methodology, combining scientific theory with computer simulation, focusing on the internal structure and features of a system (Zhong *et al*., 2013). The basic principle in SD, is modelling system's structure in order to understand the behaviour the system produces (Sterman, 2000). Through modelling it is easier to see the cause-and-effect relationships developed, resulting from the feedback loops, existing between the objects of the system. These relationships can be negative, positive or stock-and-flow, meaning that a variable's change will affect other variables in the system, including also the initial one. By fully understanding and identifying the relationships into a system, the analyst can understand the behaviour of the whole system. The main steps followed in a SD modelling process are: (a) *problem structuring*, (b) *causal loop modelling*, (c) *dynamic modelling* and (d) *communication of results* (Maani and Cavana, 2000).

In a system there are many variables connected with arrows and influence lines, forming many causal chains and loops. Influence lines' directions express the impact of a causal chain. Analytically, the '+' sign on the upper end of an influence line, designates that the two variables on both sides of the line change in the same direction, while '-' sign stands for the opposite. Thus, feedback loops can be considered as positive or negative, based on all variables and influence lines. Negative loops tend to a balancing situation, while positive loops exhibit an unstable situation (Georgiadis *et al*., 2005). Causal-loop diagrams can be created once all parameters have been identified and constitute the groundwork of the SD model. The representation of the model is accomplished through a stock-and-flow diagram according to the causal loops (Egilmez and Tatari, 2012). Stock-and-flow diagrams help analysts to perform the quantitative analysis. Stock variables reflects the state of the system, while flow variables carry the diversifying stocks which express the flows in a system.

In recent years due to the technological development, many great simulation (computational) tools have been created to support SD. The most prevalent are the DynamO (Forrester, 1961), iThink from ISEE systems, Vensim from Ventana systems Inc. and Powersim from Powersim Software AS.

1.2. Multi-agent systems

According to Taniguchi *et al*. (2001) conventional modelling methods being used in urban logistics, such as optimisation or other statistical or probalistic methods, are not sufficient to capture the heterogeneity, complexity and unpredictability of the stakeholders within the decision making process.

These methods are deterministic, meaning that they cannot provide knowledge in the whole logistics process and cannot incorporate dynamics into the system. Therefore, the need of identifying the interrelationships among stakeholders and measuring their effect in sustainable urban logistics policy analysis, can be served through a Multi-Agent System (MAS). In the field of urban logistics several researches have been conducted using MASs to evaluate smart logistics solutions. Duin *et al.* (2012) developed a MAS to evaluate an Urban Distribution Centre as well as to analyse the arising dynamic behaviour of stakeholders. Graudina and Grundspenkis (2005) evaluated the performance of intermodal terminals for urban freight, based on a detailed description of the intra-terminal processes. Teo *et al.* (2012) presented a MAS model for evaluating an e-commerce delivery system solution. This was achieved by combining vehicle routing and scheduling problem via time window auction theory. Tamagawa *et al.* (2010) built a MAS model that concerned truck ban and discounting motorway tolls, considering freight carriers, shippers, residents, administrators and motorway operators. Taniguchi *et al.* (2007) examined the produced financial benefits and costs for freight carriers and shippers after implementing road pricing. Finally, Wangapisit *et al.* (2014) explored the implementation of joint delivery system and car parking management as city logistics measures.

The functional framework of this technique consists of three stages: *specification* in which information related to the decision structure is gathered, *validation* which refers to the validation of the developed model in respect to base models and *analysis* in which all different scenarios and outcomes of the evaluation of the model are counted in to recommend the most appropriate solution (Anand *et al.*, 2015). A MAS establishes every stakeholder category as an independent entity which focuses on specific aspects of a solution, by creating modular objects, the 'Agents'. Given that two or more 'Agents' are enabled in the decision making process of a policy, MASs consolidate the individual capabilities, knowledge, objectives and viewpoints of the involved agents, and through cooperation, negotiation and co-ordination help them reach their common goal (Durfee *et al.*, 1989). The system can be very flexible in terms of actors' participation since a high number of agents can be involved. Moreover, MASs have been used in many complex real systems, which operate in unpredictable environments and are able to measure the impact of multi-agent strategies (Horling *et al.* 2000). In such cases, what makes a MAS more suitable over other traditional methods is mainly the distribution of the system. This distribution (decentralization) makes the system less sensitive to certain risks, but this comes in trade-off with the increase of difficulty to analyse comprehensively the overall performance of the system (Braubach *et al.*, 2004).

MAS is a relatively new simulation technique with increasing applications in recent few years. Frequently applied methods in such systems are MASCOT, CoagenS, Agend Enterprise, TELETRUCK and VRPTW-D (Hellingrath, 2009; Graudina and Grundspenkis, 2005; Taniguchi *et al.*, 2007).

1.3. Traffic simulation

Micro, meso and macro simulation has been proved to be a valuable tool for planning, designing and evaluating the contribution of the urban goods transport to urban mobility and environment. Simulation of different scenarios can be assessed on the basis of interaction of city's traffic related attributes e.g. transport infrastructure system, local driving regulations, modal split, traffic volumes etc., with the properties of the proposed UFT measures. On market, there are various simulators, which can evaluate directly the impacts of the concerned measure in two principal sustainability impact areas (a) *environment* and (b) *transport.*

Several software tools exist that can be used for simulation. The most prevalent for micro simulation are Vissim from PTV, AIMSUN from TSS- Transport, CORSIM by US Federal Highway Administration, SUMO from DLR, PARAMICS from Quadstone Limited, vtSim from Technical University of Munich and more. However, all models that will be designed for a specific case, need calibration in order to produce credible and reliable models. Calibration is a prerequisite to replicate accurately the real traffic situations of a system. Along with the calibration process, a validation process to verify the credibility of the model under fresh field data is also needed. The process of calibration and validation should be included as principle precondition also in meso and macro simulation. Software tools for macro and meso simulation are VISUM (macro simulation) from PTV, AIMSUN (meso & macro simulation), DYNACAM (macrosimulation) by US Federal Highway Administration, MATSim (meso and macro simulation) by Technical University of Berlin, OpenTrafficSim (micro, meso and macro simulation) from Delft University of Technology, Repast (meso and macro simulation), MAINSIM (meso and macro simulation), TRANSIM (macro simulation), Carsim (meso and macro simulation), osmtraffic (meso and macro simulation) and other.

Many studies in literature dealt with the evaluation of logistics solutions through micro, meso and macro simulation. Queshi *et al*. (2012) presented a micro simulation-based evaluation of the soft time windows variant of the Vehicle Routing Problem (VRP) with Vissim. Gattuso *et al*. (2014) developed a micro simulation model to evaluate a logistics platform in the agri-food sector. Taylor (2005) examined urban freight transport with macro simulators within the City Logistics Paradigm in the city of Sydney, Australia in order to increase transport system's performance. Scroeder *et al*. (2012) presented a multi-agent freight transport model using the MATSim simulation software for a fictitious system. In their example, the two groups making the logistics decisions, are the transport service providers and carriers. Walker and Manson (2014) showed in their study the development of a micro simulation traffic model, concluding that more telematics does not necessarily lead to more efficient urban logistics, since topography of urban street layout is an important contingency variable. Hosoya *et al*. (2003) developed a micro simulation model of the metropolitan area of Tokyo, Japan in order to evaluate four logistics policies in Vehicle-Kilometer-Traveled (VKT) NO_x and costs terms, considering also individual firm's behaviour and their characteristics. Their evaluation concluded that the most effective measure in this simulation was road pricing.

2. Evaluation

Comprehensive estimation and evaluation of the effects of logistics solutions is required, whether a solution will be finally implemented or not (Hosoya *et al*., 2003). Since sustainability of logistics solutions is the goal to be reached, their evaluation should be projected to the four sustainability impact areas. According to Nathanail and Papoutsis (2015), sustainability in urban distribution can be expressed through sustainability in the following core impact areas:

- *Economy*: Economy is considered the impact area that includes all benefits and costs deriving from the implementation of a measure. Economy encloses also the aspect of energy, i.e. energy availability, demand, price and consumption. In order to achieve a sustainable economy both the financial perspectives and the energy utilization of the concerned solution(s), should be sustainable, as well.
- *Environment*: Environmental impact includes the evaluation of the impact of the logistics system in terms of emissions, air quality, noise, and waste products. Ultimate goal during or after the implementation of a UFT solution is the preservation of natural resources and mitigation of the negative effects on the ecosystem. Environmental impacts may refer from local to bigger natural ecosystems (on regional scale).
- *Transport*: Transport area refers to the upkeep of a high quality urban freight transport system. Attractiveness, accessibility, level of service, safety, reliability are all aspects taken into account to evaluate system's transport and mobility. Individual sustainability in all the aforementioned aspects constitutes a prerequisite, for achieving overall transport sustainability.
- *Society*: The societal impact area considers all impacts on the liveability of the concerned urban area, i.e. public health, convenience, accidents, nuisance and living standards. Again, this impact area is considered sustainable, when all aspects compounding the liveability in a society, are considered sustainable too.

Moreover, several stakeholder categories are usually involved into the decision making and therefore, into the evaluation process. The evaluation for each stakeholder category can be realized by setting one single criterion (monetary) or several criteria (non-monetary). When several individual criteria are set by two or more stakeholder categories, then the evaluation becomes multi-stakeholder multi-criteria evaluation. In this case, a global index (quantified result) can be estimated by combining the individual indexes per solution with the relevant weights for each stakeholder category for each impact area. A Delphi process could be used to 'assign' weights per stakeholder category, once a 70% consensus is achieved (NOVELOG, 2016a).

2.1. Stakeholder categories

Clarkson (1995) stated that an organization's development satisfaction, derives directly from the level of satisfaction of all primary stakeholder categories involved. Urban logistics is an open and dynamically changing system where various stakeholder categories are involved, with conflicting objectives, autonomy and divergent viewpoints. The successful implementation of an urban freight solution, highly depends on the eurhythmic cooperation of these stakeholders. Primary stakeholder categories in literature can be found under different naming and clustering based mainly on the activity performed. Taniguchi *et al*. (2012) see four stakeholder categories in urban freight transport domain: *shippers*, *freight carriers*, *administrators*, and *residents (consumers)*. Under a different approach, Russo and Comi (2011) distinguish stakeholders as those who make decisions (*public authorities, private companies and public-private partnerships)*, and those groups who have to abide by these decisions (*end-consumers, receivers, shippers and wholesalers or retailers)*. Gonzalez-Feliu *et al*. (2010) assort stakeholders as *loaders (senders or receivers)*, *transporters (third-party transportation companies)* and *the owners and management companies (of warehouses, cross-docks and other infrastructure)*.

This analysis follows stakeholders' group pattern according to NOVELOG (2016b). This pattern is preferred since the clustering made is broad, taking into consideration all primary stakeholders. The stakeholder categories are (NOVELOG, 2016b):

- *Supply Chain Stakeholders* (Freight Forwarders, Transport Operators, Shippers, Major Retail chains, Shop owners)
- *Public Authorities* (Local Government, National Government)
- *Other Stakeholders* (Industry and Commerce Associations, Consumer Associations, Research and Academia.

2.2. Smart logistics solutions

After 1990, severe logistics problems in urban areas draw the attention of researchers and policy-makers. Research activities started focusing on initiatives to alleviate cities' problems, such as restriction measures and consolidation centres (Kohler, 2004). However, over the next years, goods' increased transport deteriorated further the traffic situation in cities with clear negative impacts in other areas i.e. environment and society, too. In order to mitigate these adverse effects many methodical approaches were identified and developed by government agencies, researchers and companies.

An extended list of current logistics solutions is included in NOVELOG (2016b). These solutions are grouped in two categories: (a*) cooperative logistics* and (b) *administrative & regulatory schemes and incentives*. The logistics solutions are presented in Table 1.

Table 1. Smart Logistics Solutions (Source: NOVELOG, 2016a)

Smart Logistic Solutions	
Cooperative Logistics	Administrative & regulatory schemes and incentives
Multimodality for urban freight	Loading/Unloading areas and parking
Urban consolidation centres	Access: time windows, emission zones
Trans-shipment facilities	Access by load factor
ITS for freight monitoring and planning/routing	Multi-users lanes
Home deliveries system	Enforcement and ITS adoption for control and traffic management
E-commerce system for small shops	Businesses recognition scheme
Cargo bikes gor B2B and B2C	Public transport indirect promotion for shopping
Electric vehicles diffusion in businesses (zero-emission transport)	Urban planning measures
Reverse logistics integration into supply chain	Harmonization and simplification of city logistics rules
Lockers introduction	Off peak deliveries
	Public transport for freight

3. Review of smart logistics measures' simulation techniques

The review framework that follows, is based on 16 scientific studies that have been performed within the last 15 years. These studies' focus lies on the evaluation of smart logistics solutions through simulation techniques. The structure of the review is shaped in four columns which describe the *logistics solution*, the *simulation technique*, the *stakeholder category* and each study's data (*author & year*). Finally, the nomenclature of some logistics solutions has been adjusted to fit in one of the 22 logistic measures, as described in Table 1. The review summary can be seen in Table 2.

Table 2. Review of city logistics model techniques

Logistics Solutions	Simulation Technique	Stakeholder Category	Author (Year)
Cargo bikes for B2B and B2C, Home deliveries system	Traffic simulation	Public Authorities	Munuzuri *et al*. (2010)
ITS for freight monitoring and planning/routing (Route-based guidance for delivery/pick up vehicles)	Traffic simulation	Other stakeholders	Walker and Manson, (2014)
Access by load factor (Truck ban and tolling of urban expressway)	Multi-agent systems	Supply Chain Stakeholders, Other stakeholders	Taniguchi and Tamagawa (2005)
E-commerce system, Access by load factor, Access: time windows, emission zones, Enforcement and ITS adoption for control and traffic management	Systems Dynamics	Public Authorities	Qiu *et al*. (2015)
E-commerce system (vehicle routing and scheduling)	Multi-agent systems	Supply Chain Stakeholders, Other stakeholders	Teo *et al*. (2012)
Urban Consolidation Centre (Dynamic Usage of UCC)	Multi-agent systems	Supply Chain Stakeholders, Public Authorities	Van Duin *et al*. (2012)
Urban Consolidation Centre & Loading /Unloading areas and parking (Joint delivery systems)	Multi-agent systems	Supply Chain Stakeholders	Wangapisit *et al*. (2014)
Intermodal terminals for urban freight	Multi-agent systems	Supply Chain Stakeholders	Graudina and Grundspenkis (2005)
Access by load factor and time windows (Truck ban and discounting motorway tolls)	Multi-agent systems	Supply Chain Stakeholders, Other stakeholders	Tamagawa *et al*. (2010)
Access by load factor	Multi-agent systems in combination with Traffic simulation (MATSim) (Freight micro-models)	Supply Chain Stakeholders	Schroeder *et al*. (2012)
Access: Time windows	Traffic simulation	Supply Chain Stakeholders, Public Authorities, Other stakeholders	Qureshi *et al*. (2012)
Loading/Unloading areas and parking	Traffic simulation	Supply Chain Stakeholders	Gattuso *et al*. (2014)
Access by load factor, Urban Consolidation Centre	Traffic simulation	Supply Chain Stakeholders, Public Authorities	Hosoya *et al*. (2003)
Reverse logistics integration into supply chain	Systems Dynamics	Supply Chain Stakeholders	Poles (2013)
Business recognition scheme	Systems Dynamics	Supply Chain Stakeholders	Tan and Blanco (2009)
Access by load factor, Access: time windows, emission zones, Off peak deliveries, Urban consolidation centres	Multi-agent systems	Supply Chain Stakeholders, Public Authorities	Teo *et al*. (2014)

The review shows that the most frequently used simulation technique is the ‘Multi-agent systems’, which in combination with the ‘Traffic simulation’ technique is used in 13 studies (59.1%). This conclusion can be easily justified considering that the overall evaluation and decision making process in the logistics domain, cannot be examined only under a single set of criteria, established by one stakeholder category (agent). The objectives of each stakeholder category are rather divergent and in many cases even conflicting. Therefore, sustainability for a logistics solution should be checked in many aspects and under several viewpoints.

To continue, out of the 22 UFT solutions, only 12 (54.5%) have been examined in simulation models. The most frequent solution is the ‘Access by load factor’, while many deployed models test truck ban and road restrictions in combination with limited access in urban centres, especially during peak hours. ‘Urban consolidation centres’, ‘e-commerce systems’ and ‘ITS adoption for scheduling/routing and traffic management’ are also frequent solutions that are assessed in simulation modelling. Finally, the majority of the existing models (75%) has been deployed after 2010.

4. Concluding Discussion

This paper analysed the emerging simulation techniques currently used for the evaluation of smart logistics solutions. Apart from the state-of-art, the authors made an effort to enhance knowledge around modelling in the urban freight domain and provide guidance to future decision makers, based on the stakeholder category they belong to and the type of solution they want to adopt. Furthermore, this review constitutes a roadmap for stakeholders willing to evaluate a logistics solution. Stakeholders as decision makers for the implementation of a logistics solution, can be guided from similar studies regarding the simulation technique that has been applied, the results, potential complications and other information that might be proven as useful for the decision making process.

4.1. Further Research

Based on the knowledge gained through this paper, authors believe that the incorporation of optimisation models in this review, may formulate a compact data source, where a decision maker will be able to trace back developed models for respective logistics solutions. This compact data source could be further enriched over the following years, when more simulation models will have been deployed and additional simulation and optimisation techniques may have been developed.

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METHODOLOGICAL FRAMEWORK FOR THE EVALUATION OF URBAN FREIGHT TRANSPORT INTERCHANGES FOCUSING ON URBAN CONSOLIDATION CENTRES (UCC)

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Over the last decade, the focus in the domain of freight transport has been set on the investigation of ways to eliminate time and cost in last mile delivery, while continuously upgrading the level of provided services, promoting a number of innovative logistics solutions. One of the most important issues is the optimization of the interconnection amongst the interurban and urban sections of the supply chain, where the role of the Freight Transport Interchanges (i.e. Freight Centres) has been fundamental. The key issue is three fold and the optimum solution lies between: a) the selection of the most appropriate location for the establishment of each facility and b) the identification of the facility's attributes that should much the interest area's needs and c) the evaluation of the concept as considered to be part of the local UFT policies and measures promoted or planned for the area of interest. The answer to the afore mentioned issues is provided through a two level approach incorporating the development of two discrete, but successive decision making supportive evaluation tools. First, a methodological approach is developed in order to provide a solution to the facility location problem for Freight Centres with focus on UCCs. Going one step further, it is combined with the integrated evaluation framework used for the assessment of Urban Freight Transport (UFT) policies and measures, developed within the NOVELOG project, accordingly modified to meet the UCC concept requirements. Both methodological frameworks enable the assessment of UFT and logistics solutions focusing on Freight Centres and especially UCCs, based on selected performance indicators, incorporating divergent stakeholders' interests and taking into consideration conflicting business models and operations.

Keywords: evaluation, framework, UFT, Freight Centers, UCC, optimization

1. Introduction

The burdening of the urban environment is highlighted by the fact that over 50% of the world population lives in cities (in Europe it is more than 75%), with this percentage expected to reach 70% worldwide by 2050. The freight transport interchanges have been developing during the last five or six decades, with view to better coordinate the continuously increasing freight flows. Especially during the last two or three decades, there has been a considerable increase in the freight transport needs in both interurban and urban context, resulting in deep impact on human and natural environment. In most of the cases, the seamless movement of cargo throughout the whole supply chain and the interconnection of interurban and urban transportation networks are accomplished through the establishment and operation of intermodal freight transport interchanges, the Freight Centres or just hubs. Starting from France in the sixties as small warehouses, today they constitute integrated, multi-tasking, multi-modal and multi-stakeholder facilities. Through the years, the Freight Centres have evolved and been modified both as per their orientation, from local to regional, national, international or global and as per their type, incorporating freight transport activities together with commercial, socio-economic and business aspects (BESTUFS 2008; European Commission, 2014; United Nations, 2014; Gogas and Nathanail, 2010, 2014; Gogas *et al*., 2016).

A great number of attempts towards the determination of Freight Centre typology and categorization have been elaborated within the past two or three decades. Today, according to their operational profile and their location, the Freight Centres are classified in four (4) discrete categories (Visser *et al.*, 1999; Reform 2002; IMONODE, 2005; Nathanail, 2007; Wisetjindawat, 2010):

1. **Business grouping development areas or City Terminals**: Units located in the vicinity of big cities, aiming at the alleviation of traffic problems recorded in the city web due to freight activities such as loading – unloading, shifting between transport modes, packaging – unpackaging, handling and unitization of cargo and coordination of its distribution etc. They constitute one of the fundamental factors shaping the economic profile of the city, while the space engaged by their infrastructure is usually small, due to the very high land use price.
2. **Freight Villages**: Units located usually far from cities, in large areas (low land use price). Their role is similar to the one of City Terminals, but their catchment area expands beyond city or peripheral borders and often reaches the national or even international level. They also have excellent and direct connections and accesses to road and railway networks (regional, national and international).

3. **Industrial and logistic parks**: Units located usually far from cities, in large areas (low land use price). Their role, apart from the alleviation of city centres from traffic problems, is the economic development at regional level. In such units, except for transport and logistics companies, several industrial enterprises are established, as well.
4. **Special logistic areas**: Units located in large areas near sea / river ports and airports, often within large cities, aiming at the supporting of the freight activities involved, but also promoting the regional economic development, even though they focus on serving the city needs. Apart from the road and rail connections, such units have excellent and direct access to sea, inland waterway and air transport network.

As far as the classification of Freight Centres according to their size (determined by the total space engaged by their infrastructure) is concerned, there are Freight Centres characterized as (Reform and IMONODE projects, 2005) small sized (up to 50000m^2), medium sized (from 50000m^2 to 500000m^2) and big sized (over 500000m^2). The property status, administration, management and operation of the Freight Centres is either public issue (regional, public or national authorities, port authorities etc) or private issue (transport companies or associations, logistics providers, infrastructure providers etc), but within the last two decades, the model of Public Private Partnership seems to be prevailing. In any case, the performance of freight terminals relies on the performance of multiple processes that are undertaken within these areas. The role and performance of terminals that are located in the outskirts of the cities, such as city terminals, affect the performance of urban distribution to a large extent and consequently determine the structure of city logistics (Europlatforms, 2016).

This paper is focused on Urban Consolidation Centres (UCCs), categorized as City Terminals, i.e. large facilities usually located within the suburban area of big cities and their role is the infrastructural, operational and service optimization of the interconnection of the interurban and urban sections of the supply chain. In UCCs the intercity cargo is assembled and appropriately grouped in order to be forwarded for last mile distribution. A UCC is best described as a logistics facility that is situated in relatively close proximity to the geographic area that it serves, be that a city centre, an entire town or a specific site (e.g. shopping centre), from which consolidated deliveries are carried out within that area. A range of other value-added logistics and retail services can also be provided at the UCC. Broadly speaking the key purpose identified for UCCs is the avoidance of the need for vehicles to deliver part loads into urban centres or other large developments. This objective can be achieved by providing facilities whereby deliveries can be consolidated for subsequent delivery into the area in an appropriate vehicle with a high level of load utilization (Browne *et al.*, 2005).

The UCCs play a key role with the supply chain, as they constitute the nodal points where the cargo assembled is transhipped from large and polluting heavy good vehicles (HGVs) and freight transport units, to smaller, cleaner – environmental friendly and more flexible ones performing the last mile distribution in urban areas, in order to protect urban and restricted areas from traffic congestion and impact on environment, safety and quality of life. Such city logistics techniques, although it may seem cost and time consuming, have been proved to be cost effective, traffic alleviating and environmental preserving (Grimm *et al*., 2008; Janjevic *et al*., 2013; Janjevic, 2015).

Incorporated within the most common Urban Freight Transport (UFT) policies and measures worldwide, the UCC is believed that it contributes to the upgrading of the local urban economy, mobility, sustainability and liveability. The UCC concept is included amongst the most popular measures that have a consolidation aspect, i.e. the bundling of goods in order to increase the load factors and therefore decrease the number of necessary journeys needed to perform the deliveries. In other words, the key purpose of UCCs is the avoidance of the need for goods vehicles to deliver part loads into urban areas. According to Danielis *et al*., (2010), the introduction of a UCC constitutes an appealing policy aiming at changing the quantity and quality of deliveries. In any case, it seems that the UCC concept has been broadly ranked at first places when it comes to the application of smart logistics solutions. In proof of the previous statement, Allen *et al*. (2012) elaborated an international comparison of 114 UCC schemes in 17 countries over last 40 years highlighting the growing interest towards the realization of UCCs (42 schemes between 2006 and 2010). However, experience has proven in practice that only in a very few cases the UCCs survived financially without structural and continuous public subsidies or strong political commitment, so their sustainability and economic liveability is dependable and doubtful (Marcucci and Danielis, 2007; Danielis *et al*., 2010; Ville *et al*., 2012; Verlinde *et al*., 2012; Kim *et al*, 2015).

The paper deals with the analysis of attributes and characteristics as well as the evaluation of the efficiency and performance of Urban Consolidation Centres (UCCs) which are incorporated in the category of City Terminals. The paper is structured in four sections, including the introduction, where a first approach on the Freight Centres' scheme is attempted in order to present to the reader the backbone and general concept of the Urban Consolidation Centre, together with a brief state of the art review on

UCCs development. The second section is dedicated on the development of a methodological decision making framework used for the selection of the most appropriate location for Freight Center establishment, tailor made for UCCs. The third section incorporates the methodology used in NOVELOG project for the evaluation of the efficiency of Urban Freight Transport - UFT policies and measures accordingly suited to the case of UCC. Focusing on "UCC concept", some interesting conclusions and directions for further research on the application and testing of the two methodologies in real life conditions are briefly presented and commented within the last section of the paper.

2. UCC facility location

The facility location problem has been studied for over 100 years, initially introduced as 'Plant and warehouse location problems' or "Fermat-Weber problem" (Weber, 1909). Up until today, a great number of methodologies, models and software packages have been developed. The problem has to do with the investigation and selection of the most appropriate location for facility establishment, it constitutes a decision making issue with considerable socio-economic, business, environmental, safety and traffic impact and interrelation with the area of influence (Gogas and Nathanail, 2014). In this paper, a multi stakeholder multi criteria methodology is introduced to provide a solution to the UCC location problem, taking into consideration both qualitative and quantitative parameters (criteria). Each criterion is further analysed in a set of respective indicators. The qualitative criteria (Table 1) cover seven fields of interest.

Table 1. Qualitative criteria (Gogas *et al.*, 2010, 2014, 2016)

Criteria	Indicators
Competitiveness	Supporting of industrial development – improvement of existing logistics infrastructure and / or development of new one.
	Use of ICT, innovative technologies and equipment for the modernization of freight transport domain.
	Improvement of competitiveness of intermodal versus unimodal transport (cost, time, safety).
	Improvement of the UCC's adjacent area and area of influence competitiveness in the transport market.
Organizational and institutional structure	Provision of fair and equal access to involved stakeholders and potential users or customers, i.e. whether all companies have access to the services provided by the UCC on equal conditions.
	Degree of independence of UCC management from transport operators and local actors.
	Institutional complexity, i.e. number of institutional levels involved in the interchange planning.
	Management policy, i.e. potential organizational scheme of UCC according to its location, the stakeholders or shareholders attracted and the involvement of public and private domain, according to legislative framework and local or regional UFT policy and regulations.
Business and marketing	Strengthening the UCC's (and adjacent area's) role as a hub in the freight transportation market.
	Attracting of companies, partners and potential stakeholders.
	Degree of attraction of region for the installation of new businesses.
	Level of development of synergies amongst businesses and building of robust collaboration and business schemes (e.g. PPPs) amongst stakeholders.
Spatial and socioeconomic development	Degree of attraction of flows through polycentric spatial development.
	Optimization of land use development (mitigation of logistics land uses from congested or environmentally protected areas, reduction of required space through the concentration of logistics activities in specific areas and the establishment of special logistics zones).
	Socioeconomic development and logistics cost reduction.
	Contribution to the economic and territorial cohesion of the adjacent area.
	Level of social security.
	Energy and / or fuel cost or savings.
Level of service	Handling time and respective costs per cargo unit.
	Origin –Destination route according to UCC's location, provided transportation network and location of interest area's commercial zone and profile of vehicles' roundtrip.
	UCC integration level, i.e. proximity and access of terminal to auxiliary services (e.g. customs).
	Elimination of bottlenecks (e.g. delays) and increase of vehicle speed and load factor through better routing.
	Improvement in the accessibility of products to the markets as concerns cost and time - Punctuality and reliability in time of freight movements (e.g. cargo assignments and deliveries).
	Supply chain visibility – monitoring and information availability (warning or alerts in case of emergency).
	Safety and security level including accidents, thefts and crime.
	Introduction of added value services.
	Increase customer satisfaction
Quality of life improvement	Reduction of environmental pollution, noise and visual nuisance due to freight traffic especially near or inside urban areas or protected environmental zones.
	Shift of market share from road to the more environmental friendly combined transport with priority on rail.
	Promotion of interurban – urban mobility and accessibility issues.
	Reduction of total price paid by the customers and consumers through economies of scale, aggregated cargo, goods' consolidation and unitization and accumulated goods handling and delivery.

Promotion of European transport policy and funding	Economic and territorial cohesion – harmonization of the economic development.
	Increase degree of compliance with the EU transport directives - Building conditions for more requested funding from EU.
	Promotion of EU policy on transport and adoption of innovative methods and solution – education of involved stakeholders.
	Better exploitation of EU funding according to strategic planning and designing in the area of influence.
	Compliance with EU's policy on the protection of environmental sensitive areas (e.g. Ramsar convention).

Accordingly, the quantitative criteria are spread over another 6 fields of interest (Table 2).

Table 2. Quantitative criteria (Gogas *et al.*, 2010, 2014, 2016)

Criteria	Indicators
Geostrategic location	Distance (Km) from industrial zones.
	Distance (Km) from ports.
	Distance (Km) from airports.
	Distance (Km) from Freight Centres (including other UCCs in the area of influence).
	Distance (Km) from transport and transhipment companies.
	Distance (Km) from commercial centres.
	Distance (Km) from agricultural or agribusiness centres.
Transportation	Total local, regional or national annual freight flows (tons) potentially attracted and handled by the UCC (long haulage and distribution).
	International transit flows (tons) passing through the catchment area of the UCC potentially attracted and handled by it.
	Percentage of increase of traffic flows (with versus without UCC situation).
	Type of connection to the national motorway network (direct / indirect).
	Distance from the national motorway network (Km).
	Type of connection to the international motorway network (direct / indirect).
	Distance from the international motorway network (Km).
	Type of connection to the national railway network (direct / indirect).
	Distance from the national railway network (Km).
	Type of connection to the international railway network (direct / indirect).
	Distance from the international railway network (Km).
	Type of connection to maritime or river port terminals (direct / indirect).
	Type of connection to hub-airport terminals (direct / indirect).
Appropriateness of land	Present saturation ratio of UCC (current demand flows handled over capacity).
	Anticipated saturation ratio of UCC (future or potential demand flows handled over capacity).
	Potential expandability (percentage of expanding the available size of UCC).
	Topography (elevation: flat, semi mountainous or mountainous).
	Technical appropriateness (important – urgent, small or insignificant need for infrastructure building, maintenance or removal).
	Availability and sufficiency of superstructure, utility networks and equipment (important – urgent, small or insignificant need for superstructure purchasing, maintenance or removal).
	Complementary and supporting activities needed (y/n and what type / budget).
Environment	Distance from urban and / or environmentally sensitive areas (protected areas, water supplies, national parks and holiday resorts).
	Percentage of increase of air pollution level (considering GHG and particulate emissions).
	Percentage of increase of noise nuisance level.
	Visual impact.
Safety and security	Annual number of accidents.
	Annual number of fatalities.
	Annual number of heavy injuries.
	Annual number of damages on cargo and vehicles.
Planning security	Current property status (public, private or collaboration scheme), administrative and management structure (decision making process) – stakeholder collaboration funding scheme.
	Future planning – level of compliance with national / international / EU transportation policy at strategic level.

The significance (weight) of all criteria and indicators in the whole evaluation process are determined based on both:

- ✓ DELPHI method, in the context of which experts in the domain of freight transport and logistics from academia and scientific community provide their point of view and
- ✓ questionnaire survey, elaborated amongst the involved stakeholders (multi agent based approach), where the involved stakeholders groups provide their approach.

Each criterion and its respective indicators are compared to each other through pairwise comparison and then prioritized using the Analytic Hierarchy Process – AHP (Saaty, 2008). In the end, the criteria and indicators' significance in the whole multi-criteria process is estimated attributing to each one of them the respective weight. The stakeholders involved are separated into three groups briefly depicted below, following NOVELOG project approach (NOVELOG, 2016a):

i. Supply chain stakeholders (mostly private companies including shippers, receivers, forwarders, retailers, logistics service providers, infrastructure and equipment providers etc).
ii. Public authorities (mostly public organizations and bodies, such as local, regional and national authorities or politicians).
iii. Other stakeholders (mostly general public as users, customers and consumers).

According to the stakeholder group's influence in the decision making, a respective weight is attributed to them. In most of the cases, those weights are equal to each other and sum up to 100%. In addition, all criteria weights sum up to 100% and all respective indicators' weights in each criterion sum up to 100%. With view to increase the objectiveness of the evaluation process results, it is suggested that after the production of the final results, the evaluation process should run again in many iterations, elaborating a sensitivity analysis. Within each iteration, the slight modification in criteria and indicators' weights (no more than a 10% increase or decrease), provide for further validation of results.

Usually, the decision maker has to select amongst many alternatives. Each alternative case or situation (e.g. current and future or before and after the realization of a UCC) in the area of interest is described through the building of the respective scenario. For the qualitative indicators, the level or percentage is usually estimated using the likert scale, while for the quantitative ones, numerical values have to be provided. The numerical values in each scenario are estimated through data collection process elaborating investigation, research, questionnaire surveys, measurements, estimations and assumptions.

Finally, the performance of each alternative solution or scenario is estimated as the weighted sum produced by the multiplication of each indicator value, with the respective indicator weight, with the criterion weight and with the involved stakeholder group weight. In this way, the total performance index of each scenario is estimated. However, a partial performance index may be estimated accordingly for each criterion or per stakeholder group. The afore mentioned indices are used in order to compare the alternative solutions or scenarios with each other and rank them in order to support decision making.

3. UCC evaluation

This section is dedicated on the development and presentation of the Evaluation Framework used in NOVELOG project, so its structuring parameters and attributes are depicted. The UCC concept is examined and analysed assessing the efficiency of its attributes, provided services and interrelation with the surrounding area. The framework uses scientifically proven methodologies, considering the UCC concept through a life cycle sustainability approach, mapping the activities, involved stakeholders and impacts through all its life cycle phases from creation - construction, through operation and maintenance to closure – disposal – back logistics. The framework is composed of five (5) modules:

1. The Social Cost-Benefit Analysis Module (SCBM). It correlates life-cycle processes for UFT measures' realization with economic parameters and social costs and benefits.
2. The Impact Assessment Module (IAM). Depending on the candidate city particularities and also according to the city needs, objective goals and expectations, it develops a support choice mechanism for identifying the proper methodology to be adopted providing guidance for assessing impacts of applied UFT measures.
3. The Transferability and Adaptability Module (TAM), which identifies requirements for implementing UFT measures, maps specific problems and bottlenecks faced when implementing those measures at various implementation phases and establishes measurements for assessing adaptability and transferability of measures.
4. The Risk Analysis Module (RAM), which identifies risks in UFT measures implementation (analysis of potential risks in UFT measures implementation, classification of risks in external and internal) and advices for the corrective actions (prevent, mitigate, transfer, tolerate).
5. The Behavioural Modelling (BM), incorporating techniques for facilitating estimation of behavioural changes in adopting UFT measures, as well as for supporting qualitative data collection needed for the identification the impacts on multiple criteria, by multiple stakeholders.

The evaluation framework reflects a total of seven impact areas distinguished within two levels.

The first level comprises the four (4) impact areas called “sustainability disciplines”, incorporating economy and energy, environment, transport and mobility and society. Within the second level, the rest of three (3) ones called “applicability enablers” are included, namely: policy and measure maturity, social acceptance and users’ uptake. Each impact area is associated to respective criteria and key performance indicators (KPIs), so the Evaluation Framework and process is characterized as KPI-based.

Evaluation adopts the multi stakeholder multi criteria concept, incorporates a multiple weighting scheme and elimination and ranking techniques and models, for the facilitation of “shared” decision-making, taking into account the participation, viewpoint and contribution of all involved stakeholders to the conformation of the final decision made on the measures. The functions of the evaluation, following the concept of multi-stakeholder multi-criteria assessment methodologies, lead to the estimation of the Logistics Sustainability Index (LSI), which is similar to the total performance index mentioned above. The structure of the evaluation framework is depicted within Figure 1.

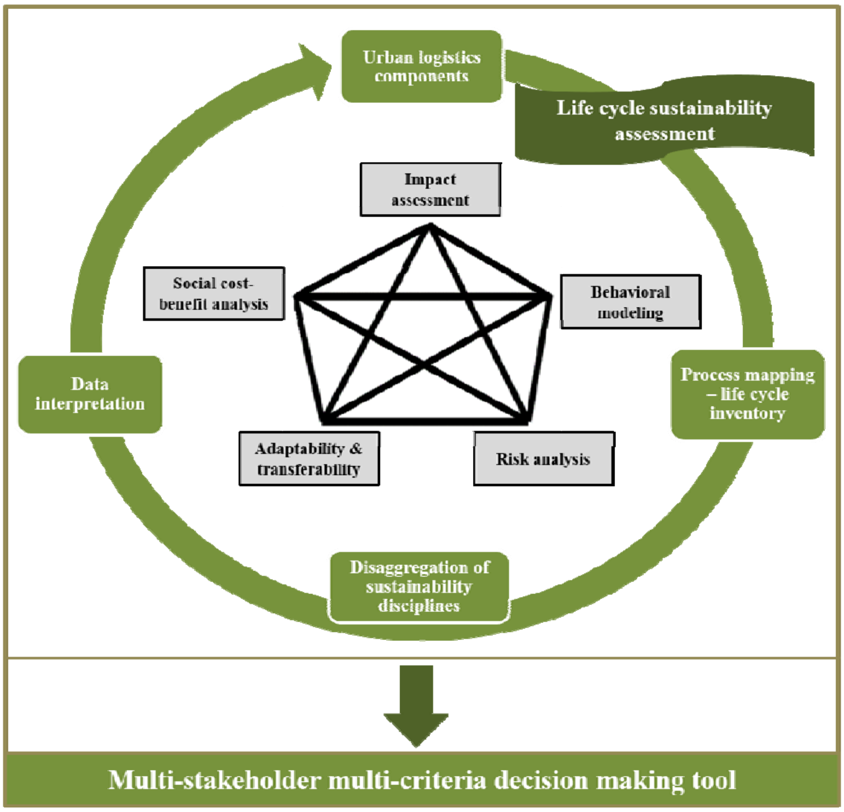

Figure 1. Structure of the evaluation framework (Nathanail *et al*., 2016a and 2016b)

Based on the four lifecycle stages (Creation – construction, Operation, Maintenance, and Closure – disposal), according to the International Standards Organization-ISO (2006), Life Cycle Sustainability Assessment - LCSA acts as the umbrella of the overall multi stakeholder multi criteria decision making framework, incorporating four (4) discrete steps:

i. Urban logistics components, five main categories of key influencing factors and measures lead to the formulation of logistics scenarios or alternatives, leading to the estimation of freight trip activities (Economy and demographics, Ecology and social responsibility, Logistics solutions, New technologies and Consumer requirements).
ii. Process mapping-life cycle inventory, incorporating four stages in the analysis, namely creation-construction, operation, maintenance, and closure-disposal (back logistics).
iii. Disaggregation of impact areas to sustainability disciplines and applicability enablers.
iv. Data interpretation, for the elaboration of estimations of numerical values.

As far as the methodological steps of the evaluation process are concerned, they are depicted in Figure 2.

The groups of stakeholders taken into consideration are the same as the ones mentioned in section 2 of the paper.

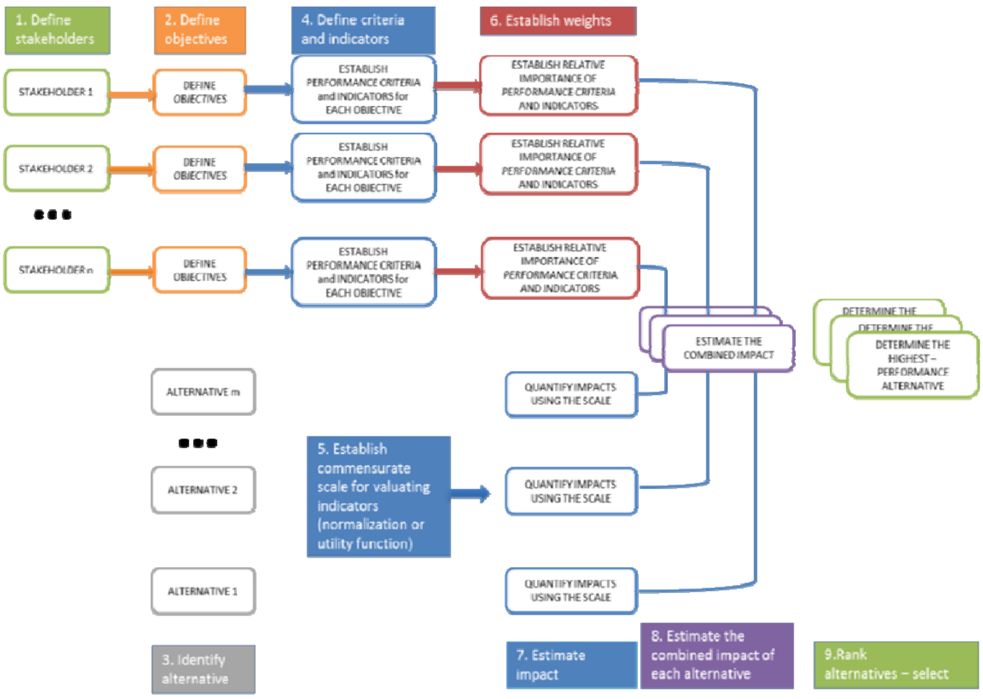

Figure 2. Evaluation process methodological steps (Nathanail *et al*., 2016a and 2016b)

The Evaluation Framework in total consists of a set of components, such as 3 different groups / categories of stakeholders (mentioned in section 2 of the paper), 4 Life Cycle Sustainability Analysis stages, 5 modules, 7 Impact areas separated into 4 sustainability disciplines and 3 applicability enablers, 26 Criteria and 140 Indicators (NOVELOG 2016a, 2016b). The evaluation framework components are independent of the UFT measure, however they are accordingly formatted based on the needs and special characteristics of the UCC concept.

It is worth mentioning that in the selection of criteria and indicators, as well as in the identification of their values and weights (significance) within the total evaluation process, together with a panel of experts (representatives from the scientific and governmental community), the local supply chain stakeholders, as well as the local society contribute, imposing their point of view and approach. The impact areas, criteria and respective indicators taken into consideration in the evaluation of each current and / or future scenario on UCC concept, are depicted within the Table 3. In particular, within the 1st column the six impact areas addressed are depicted. Within the 2nd column, the total 15 criteria are listed, while the 3rd column includes the respective indicators per criterion, adding up to 62 indicators in the total, addressing to the three afore mentioned stakeholder categories involved.

Table 3. UCC concept evaluation: impact areas, criteria and respective indicators used in the evaluation (Nathanail *et al*., 2016a and 2016b)

Impact area	Criteria	Indicators
Economy and energy	Energy	Energy consumption
	Development	Local / Regional development
	Costs	Management (Operating cost) Wages(Operating cost) Fuels (Operating cost) Warehousing and / or handling (Operating cost) Transshipment (Operating cost) Depreciation - infrastructure (Operating cost) Depreciation - equipment (Operating cost) Training - (Operating cost) Consumer cost Enforcement cost Shipper/receiver costs

Transport & mobility	Transport system	Delays
	UFT vehicles	Traffic throughput Load factor
	IT, infrastructure and technology	Underdeveloped transport infrastructure or the lack of it Low quality of transport infrastructure Limitations at developing and changing the existing infrastructure Lack of or limited access to modern technologies (eg. high-speed internet) Lack of IT Incorrect assumptions for the development of IT prototype Failures of IT systems and other modern technologies Conflicting interfaces of work items Haker disturbance Network barriers Urban space engagement Infrastructure usage
Society	Greening	Green reputation
	Living Standards	Quality of life Changes in legislation at European and national level Changes in legislation at city level Changes in the guidelines for obtaining permits for various types of investmnets Extending the duration of the project due to delays in obtaining permits from local governments Uncertainty of continuation of earlier activities / established plans due to cyclical nature of elections and hence changes in managerial positions in local government Changes in consumer behavior society Aging society Large cultural diversity of society Lack of awareness of UFT users of the dangers arising from freight transport (pollution, congestion, road accidents) Bad habits of UFT users in the organisation and execution of transport in a city Protestand interference of nearby residents War Riots, strikes Natural disasters
Policy and measure maturity	Awareness	Awareness level
	Background	Research
User uptake	Stakeholder approval	Stakeholder acceptance Stakeholder percentage Adoption rate Promotion Integration
	Knowledge and experience transfer	Transfering rate
Environment	Air quality	CO concentration SOx concentration NOx concentration VOC concentration NH3 concentration PM10 concentration
	GHG emissions	CO_2 CH_4 N_2O
	Noise	Noise level

The values of criteria and indicators may be estimated based on both experts' and involved stakeholders' opinion estimations and assumptions and on data collection, measurements, investigation, research and questionnaire surveys. All indicator values are estimated for the each scenario and are normalized following the min max normalization approach, depending on the direction of the optimum value of the indicator (Patro and Sahu, 2015). Weights on criteria and indicators are attributed based on pairwise comparison with each other, following the Analytic Hierarchy Process - AHP (Saaty, 2008). The ranking of different scenarios is accomplished through the comparison of the respective total and partial performance indices, similarly to the process described for the other framework in section 2

4. Conclusions

In this paper, two discrete but successive evaluation methodologies are suggested to be applied as decision making supportive tools in order to provide assistance to candidate decision makers and policy planners when taking decisions on future investments associated with the realization of a UCC. After all, it may provide considerable help in policy makers, being an integrated decision making tool providing guidance, proof and justification on which is the best alternative, especially when it comes to strategic planning where the investment budget is high and the decisions taken directly affect the socio-economic domain, the environment and the quality of life of thousands of people. The proposed methodological frameworks are flexible and may be used in all kinds of city contexts and interurban environments in order to evaluate and rank alternative scenarios pertaining to facility location and implementation, based on the comparison of the respective scenario performances. The advantage is that the results and findings are independent of trade-offs and external factors as they are checked against subjective judgement and further validated through the elaboration of sensitivity analysis.

However, they have not yet been tested in real life applications or in the context of pilots and case studies and this is where the future research should be directed to. The tools testing should take place both in pilots and case studies in order for their efficiency to be further validated through mathematical results and experimental research findings, to identify gaps, problems and inefficiencies and proceed with the respective corrective actions in order for the refinement of both tools to be elaborated providing an integrated decision making assistance tool.

Acknowledgements

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PROVIDING GUIDANCE FOR TRANSIT MANAGERS AND OPERATORS IN ORDER TO INCREASE THE QUALITY OF THEIR SERVICES

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At each transfer point and taking into account their minimum generalized travel cost, travellers shape an optimal for them strategy to follow for their trip. This generalized cost, is strongly related with transit quality of service aspects and differentiates among different type of travellers. The quality of a service has mostly been studied in terms of marketing, as it comes from social and business sciences. One of the most known models to assess service quality is the GAP model, proposed by Parasuraman *et al.* (1985), to investigate the service quality gaps in an organization considering at the same time both costumers' and marketers'/operator's' beliefs, expectations, perceptions and standards. Five GAPs have been examined in terms of this model, between: 1) users' expectations and operators' perceptions of users' expectations, 2) operators' perceptions of users' expectations and service quality specifications, 3) service quality specifications and service actually delivered, 4) service delivery and the communications to users about service delivery and 5) users' expectations and perceived services. The present paper deals with the fifth GAP of the model, known as the quality GAP, as this is the gap that leads users' decision to select a transit service (i.e. if users expect a higher quality level than the one perceived, they tend not to use the service). This GAP has been assessed for the Greek transit system case. An internet based questionnaire was used to collect users' expectations and perceptions of 26 selected transit quality indicators, based on a 5 point likert scale. Following, a decision tree was developed using the J48 algorithm linking users' perceptions and expectations with the overall quality of service assessment. The decision tree analysis depicts the importance of various quality components in the generalized cost estimation. According to research findings, the performance indicator "Availability of information by phone, mail", was the most crucial parameter for the overall assessment of the service, while both performance and importance indicators participated in the tree formulation. Tree paths provide guidance for transit operators and/or decision makers for increasing the quality of their services and at the same time enhance performance efficiency and operation profitability.

Keywords: transit quality of service; gap model, decision trees, j48 algorithm

1. Introduction

Transit Quality of Service seems to affect significantly transit choices and users' perceptions. A lot of research has been conducted aiming to analyse users' perceptions on Quality of Service (QoS) (TRB, 1999; Eboli and Mazzulla, 2007, 2008, 2011; Dell'Olio *et al.*, 2010; de Oña *et al.*, 2012; Tsami and Nathail, 2012, 2014a, 2014b, 2014c). QoS is commonly examined based on users' perceptions and evaluations. The difference between actual and perceived QoS has been examined by a number of researchers (Eboli and Mazzulla, 2008, 2011; Tsami and Nathanail, 2014c), but the perceived level of QoS (Tsami and Nathanail, 2014a; 2014b) seems to be the one that reflects the QoS of a system from users' point of view.

Quality of Service parameters were also examined considering their impact on trip choices (Glerum *et al.*, 2011), usually focusing on users' perceptions and performance assessment. Tsami and Nathanail (2014c) examined transit quality parameters influence on the "optimal strategies" users develop before transit choices, while Glerum *et al.* (2011) examined individuals' perceptions on quality parameters regarding their influence on travellers' mode preferences.

Tsami and Nathanail (2014b) assessed the level of significance users recognize on transit quality of service indicators, aiming at developing a framework of analysis of QoS in a transit network, by investigating the key factors that influence travel choices based on the perceived overall QoS formulation of the users. In terms of this analysis a decision tree was developed, classifying the quality indicators based on the "security against crimes on bus" indicator, which was the most crucial indicator affecting the decision making process in the overall quality of service assessment. The following two most important parameters in that analysis were the "information by phone, mail" and the "cleanliness of bus exterior".

The socioeconomic characteristics of the travellers and their personal preferences formulate their perception regarding QoS (Glerum *et al.*, 2011; Tsami and Nathanail, 2014a, 2014c). Users' perceptions on transit quality of service were also analysed based on a gender classification (Tsami and Nathanail, 2014a, 2014c) proving that women travellers had higher expectations from quality parameters (Tsami and

Nathanail, 2014c). Tsami and Nathanail (2014c) proved that “stop location” is the most important indicator to a gender classification analysis of transit quality of service, followed by the indicator of “information by phone, mail”.

2. Methodology

The data of the present study were collected using an online Customer Satisfaction Survey (CSS) conducted during August 2012. A number of 211 completed questionnaires were collected and analysed.

The survey was structured in three discrete parts. In the first one the sample socioeconomic characteristics were collected along with a question to address the overall service quality assessment of the Greek transit systems. In part two, a 5-point likert scale evaluation of the importance level of 26 selected transit quality of service indicators took place, where the highest importance was indicated by the rating value of 5 and the lowest by the rating value of 1. Similarly, in the third part, respondents were asked to evaluate the performance of the same indicators (in a 5 point likert scale again), where the lowest value of 1 reflected the lowest performance level and the value of 5 the highest. The data collected from the questionnaire parts 2 and 3 were used to develop a decision tree that considered the importance travellers’ recognize and their perceptions of the performed transit quality of service indicators in the overall quality of service assessment.

The decision tree was developed using the J48 classification algorithm developed in the Waikato Environment for Knowledge Analysis (WEKA) open data mining software.

J48 is a Java implementation of the C4.5 algorithm which is an advanced implementation of the ID3 algorithm of Quinlan (1993). The tree developed was a pruning tree using the default pruning value of 2.5. The pruning decision is needed to optimize the computational efficiency and the classification accuracy in such cases. In order to reduce the size of it and at the same time avoid complexity, a pruning in the tree was applied (Breiman *et al*., 1984).

The J48 algorithm was developed following a post-pruning method. Post-pruning is the process of evaluating the decision error (estimated % of misclassifications) at each decision junction and propagating this error up the tree. At each junction, the algorithm compared the weighted error of each child node versus the misclassification error if the child nodes were deleted and the decision node were assigned the class label of the majority class.

3. Analysis

The socioeconomic characteristics of the sample are presented in Table 1 and the 26 examined quality indicators in Table 2. In the second table the selected quality indicators are represented with specific symbols that were used in the representation of the decision tree graph (Figure 1).

Table 1. Sample socioeconomic characteristics

		N	**%**
Gender	Male	96	45,5
	Female	115	54,5
		211	100,0
Age	<=20	21	10,0
	21-40	139	65,9
	41-65	49	23,2
	>65	2	0,9
		211	100,0
Occupation	Private sector employee	28	13,3
	Public sector employee	50	23,7
	Freelancer	50	23,7
	Student	64	30,3
	Pensioner	5	2,4
	Unemployed	14	6,6
		211	100,0
Mode usually used	Urban bus	152	72,0
	Trolley	3	1,4
	Metro	41	19,4
	Suburban rail	13	6,2
	Tram	2	,9
		211	100,0

Aim of travel	Work	76	36,0
	Study	42	19,9
	Markets/Shopping	20	9,5
	Entertainment	26	12,3
	Doctor/Hospital	3	1,4
	Personal issues	31	14,7
	Other	13	6,2
		211	100,0
Travel Frequency with Public Transport	Daily (>= 5 days/week)	56	26,5
	Many times in a week (3-4 times/week)	49	23,2
	Some days in a week (1-2 times/week)	50	23,7
	Occasionally (1-3 times/ month)	36	17,1
	Rarely (<1 time/ month)	20	9,5
		211	100,0
General assessment of the PT QoS	Very bad	6	2,8
	Bad	37	17,5
	Medium	101	47,9
	Good	59	28,0
	Very Good	8	3,8
		211	100,0

Table 2. List of examined transit Quality of Service indicators

Indicator	**Symbol_Indicator_Importance**	**Symbol_Indicator_Performance**
Route	IROU	PROU
Number of stops and distance between stops	INOS	PNOS
Stop location	ISLO	PSLO
Service frequency	IREF	PREF
Daily service time	ITIM	PTIM
Reliability of runs that come on schedule	IREL	PREL
Punctuality (runs that come on time)	ICON	PCON
Crowding	ICRW	PCRW
Comfort of seats	ICMI	PCMI
Air conditioning	IAIR	PAIR
Levels of noise and vibrations	INVI	PNVI
Availability of shelter and benches at stop	ISBS	PSBS
Cleanliness of vehicle interior, seats and windows	IINC	PINC
Cleanliness of vehicle exterior	IEXC	PEXC
Ticket cost	ITIC	PTIC
Availability of schedule/maps on vehicle, and announcements	IIOV	PIOV
Availability of schedule/maps at stops	IIAS	PIAS
Availability of information by phone, mail.	IIPI	PIPI
Safety and competence of drivers	ISFD	PSFD
Security against crimes on vehicle	ISEI	PSEI
Security against crimes at stops	ISES	PSES
Personnel appearance	IPEA	PPEA
Personnel helpfulness	IPEH	PPEH
Ease of purchasing the ticket	IEBT	PEBT
Administration of complaints	IACO	PACO
Use of ecological vehicles	IECO	PECO

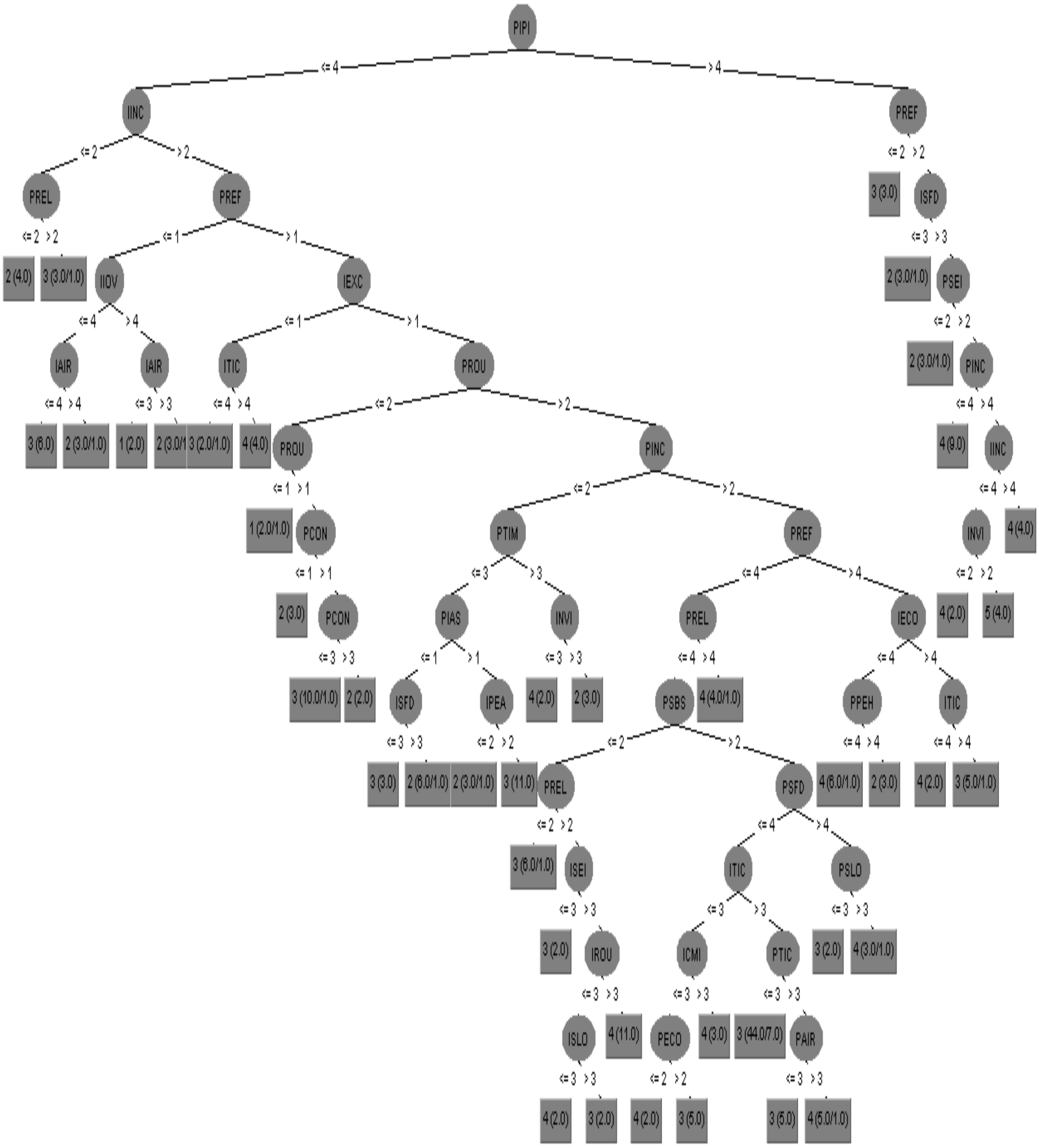

Figure 1. J48 decision tree

The tree developed through the J48 algorithm had a total size of 85 with 43 leaves (Figure 1). The time taken to build the model was 0.55 seconds and the time taken to test model on training data was 0.04 seconds. As we can notice in Table 3, the tree is considered as highly accurate with 89% correctly classified instances. The exact number of the correctly/not correctly classified instances is represented in the tree graph inside each parenthesis at the end nodes. Table 3, represents the main model output characteristics and Table 4, the detailed accuracy by classification class.

The performance of the indicator "Availability of information by phone, mail" seems to be the most important parameter in such a classification. If this indicator receives a score <=4 then the next parameter that needs to be examined is the importance transit users recognize in "Cleanliness of vehicle interior, seats and windows". In cases travellers believe that the "Cleanliness of vehicle interior, seats and windows" is below adequate important (rating <=2) then the performed "Reliability of runs that come on schedule" defines whether the overall quality assessment will be evaluated as bad (2) or medium (3).

If the importance of the indicator "Cleanliness of vehicle interior, seats and windows" is >2 and the performed "Service frequency" is perceived as very bad, the "Availability of schedule/maps on vehicle and announcements” is the next indicator that needs to be considered in the classification. If the rating of this indicator is <=4 the importance of the “Air conditioning” leads to a bad assessment of the overall service quality of the transit system in rating score >4 and a medium overall assessment in a rating score <=4. When the importance of the “Availability of schedule/maps on vehicle and announcements” has the highest evaluation score (>4), the “Air conditioning” importance classifies the sample on value 3, leading on a bad assessment of the overall quality (importance of “Air conditioning” <=3), and a bad assessment (importance of “Air conditioning” >3).

The tree is developed based on the correlations of the importance-performance quality indicators, starting from the most crucial nodes and ending to the overall assessment of the transit system scores.

Thus, the highest evaluation of the transit quality system is addressed by the following relation:
Travellers assess the performed “Availability of information by phone mail” as very good (>4), the performed “Service frequency” as >2, the importance of the “Safety and competence of drivers” as >3, the performed “Security against crimes on vehicles” as >2, the performed “Cleanliness of vehicle interior, seats and windows” as >4 and the importance of the same indicator as<=4 and the importance of “Levels of noise and vibrations” as <=2.

This path could be analysed in the opposite direction as well, and provide the “know-how” in a decision making process where for example operators aim to achieve the highest level of users’ assessment of the overall assessment of the transit quality of their services. This correlation of indicators could satisfy their target without the need to improve all 26 indicators, but only the indicators involved on this path.

Similarly, according to the tree representation, there are 13 different paths to achieve a good overall quality of service assessment (=4). The crucial paths are those with the highest scores of correctly classified instances. In this case, decision makers should follow the path:
PIPI<=4 – IINC>2 –PREF >1 – IEXC >1 –PROU >2 –PINC >2 – PREF <=4 – PREL <=4 – PSBS <=2 – PREL >2 - ISEI >3 – IROU >3.

One important notice in the above path, is that the indicator “Performed Reliability of runs that comes on schedule” (PREL) is classified two times in different steps of the path, the first time considers an evaluation <=4 and the second time an evaluation >2. Considering that the evaluation of individuals happens once, this indicator in the path needs to have a score of 3 or 4 in order to satisfy all the constraints.

Another worth mentioning notice from the tree analysis representation, is the fact that the performance level of quality indicators was used to classify the instances 23 times (23 performance nodes), while the importance level of quality indicators was used 19 times (19 importance nodes). This leads to the conclusion that the performance is more crucial than the importance assessment in the overall quality of service formulation assessment.

Table 3. WEKA J48 output

Correctly Classified Instances	**89.1509%**
Incorrectly Classified Instances	**10.8491%**
Kappa statistic	**0.8316**
Mean absolute error	**0.0663**
Root mean squared error	**0.1821**
Relative absolute error	**25.0604%**
Root relative squared error	**50.1814%**
Coverage of cases (0.95 level)	**100%**
Mean rel. region size (0.95 level)	**34.6226%**

Table 4. WEKA J48 detailed accuracy by class

	TP Rate	**FP Rate**	**Precision**	**Recall**	**F-Measure**	**MCC**	**ROC Area**	**PRC Area**	**Class**
	0.500	**0.005**	**0.750**	**0.500**	**0.600**	**0.604**	**0.987**	**0.688**	**1**
	0.811	**0.034**	**0.833**	**0.811**	**0.822**	**0.785**	**0.966**	**0.861**	**2**
	0.951	**0.109**	**0.890**	**0.951**	**0.919**	**0.842**	**0.967**	**0.948**	**3**
	0.932	**0.026**	**0.932**	**0.932**	**0.932**	**0.906**	**0.987**	**0.965**	**4**
	0.500	**0.000**	**1.000**	**0.500**	**0.667**	**0.700**	**0.990**	**0.795**	**5**
Weighted Avg.	**0.892**	**0.066**	**0.892**	**0.892**	**0.887**	**0.838**	**0.974**	**0.924**	

4. Conclusions

In terms of the present paper a decision tree was developed to address the GAP among perceived and expected quality of service attributes, considering the overall quality assessment of the Greek transit system. Using a classification tree approach this research points out that both importance and performance assessments are important for the overall quality assessment formulation.

The tree paths are linked with the overall scores of transit quality and thus the present methodology could be very useful for decision makers and transit operators in order to increase their provided level of services. The performed indicator “Availability of information by phone, mail” was proved to be the most important indicator in terms of the present analysis.

Another important finding is that the performance of the selected indicators seems to affect more the overall quality assessment than the importance users recognize for these indicators. Still, both evaluations need to be taken into account in order to cover the existing quality GAP.

The highest evaluation of the transit quality system is addressed by the tree path where travellers assess the performed “Availability of information by phone mail” as very good (>4), the performed “Service frequency” as >2, the importance of the “Safety and competence of drivers” as >3, the performed “Security against crimes on vehicles” as >2, the performed “Cleanliness of vehicle interior, seats and windows” as >4 and the importance of the same indicator as<=4 and the importance of “Levels of noise and vibrations” as <=2.

The tree provides a highly effective structure within which a decision maker can lay out quality options and investigate the possible outcomes of choosing those options. The highest QoS evaluation path should be followed by decision makers in order to address the quality indicators of intervention in order to achieve the highest overall assessment of their services.

This research used 211 responses to classify users’ assessment regarding the importance and performance scores of 26 transit quality indicators. By increasing the number of data probably the J48 tree will grow up differently. Still the high accuracy of the tree makes the analysis of the present paper proper for the aim of the present study.

Further research includes the collection of more responses in order to increase the accuracy and the validity of the tree. Similarly, data could be collected and analysed in order to address the other 4 Gaps of the Gap model, considering operators’ responses as well.

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