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Proceedings of special session in the International Conference on Sustainable Urban Mobility 2016

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FRAUNHOFER GESELLSCHAFT ZUR FORDERUNG DER ANGEWANDTEN FORSCHUNG EV – Fraunhofer	Germany

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LIST OF ABBREVIATIONS

Abbreviation	Description
CSUM	Conference on Sustainable Urban Mobility
D	Deliverable
EU	European Union
Fraunhofer	Fraunhofer Institute for Factory Operation and Automation
GA	Grant Agreement
ICT	Information and Communications Technology
M	Month
P	Paper
PO	Project Officer
STSE	Short-Term Staff Exchange
TTI	Transport and Telecommunication Institute
UTH	University of Thessaly
WP	Work Package

ABSTRACT

The present deliverable constitutes the compendium of papers presented at the 3rd Conference on Sustainable Urban Mobility by the ALLIANCE members within the scope of the project.

A statistical analysis has been performed to export useful findings regarding the papers, the authors as well as the origin (country) of the submitted papers. The aforementioned data have been summarized in tables i.e. table for recording dissemination activities, table for monitoring publications, according to the set templates.

1 Introduction

1.1 Contents of the deliverable

This document is the third deliverable of WP3 that has been prepared, along with deliverable D3.1, which outlined the knowledge-staring strategy, and deliverable D3.2 regarding the assessment of educational/training program implementation with updates by UTH. 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: research and academic staff of TTI; master and PhD students. Deliverable D3.9 constitutes the compendium of papers presented at the 3rd CSUM by the Alliance members within the scope of the project.

Papers from TTI and UTH were submitted to the 3rd Conference on Sustainable Urban Mobility (3rd CSUM) which was held on 26 – 27 May, 2016 in Volos, Greece. The International Conference was organized by the University of Thessaly, Department of Civil Engineering, Traffic, Transportation and Logistics Laboratory – TTLog, with the support of the World Academy of Science, Engineering and Technology – WASET, the European Cooperation in Science and Technology – COST, and the European Commission's project "New Cooperative Business Models and Guidance for Sustainable City Logistics" – NOVELOG. The theme of this year's Conference was "Anthropocentric approach in urban mobility planning" and its primary goal was to disseminate knowledge and exchange good practices among researchers and practitioners in the domain of urban transportation.

The Conference proceedings will be published in a special issue of Transportation Research Procedia of Elsevier (indexed in Scopus), and a selection of them will be considered for further review and publication in the International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering of the Word Academy of Science, Engineering and Technology – WASET (indexed in ISI), and the De Gruyter open access Transport and Telecommunication Journal (indexed in SCI and Scopus) of the Transport and Telecommunication Institute.

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 3rd CSUM

In total, eleven papers were prepared by the TTI and UTH staff and were submitted and presented at the 3rd Conference on Sustainable Urban Mobility. The title, the authors, the abstract and keywords for each of these papers are presented in Tables 1-11. The Conference's program is given in Annex A, while the full papers are found in Annex B.

Table 1: Paper P1 – A "Greening Mobility" framework towards sustainability

Paper code:	**P1**
Responsible or involved partner:	UTH
Paper title:	A "Greening Mobility" framework towards sustainability
Author(s):	Evangelos Bekiaris, Maria Tsami
Reference:	Bekiaris, E. & Tsami, M., 2016. "A Greening Mobility framework towards sustainability". 3rd Conference on Sustainable Urban Mobility, Volos, Greece, 26-27 May 2016.
Abstract: In terms of the present paper, the clean vehicles vision, operation and necessity are being discussed pointing out the need to raise awareness to citizens and keep them informed about the potentials of newer technologies and clean vehicle usage. The approach is based on a concise analysis of the current policies and applications, examining a number of case studies that can be considered as coming close to the notion of "green mobility" and are treated as best practices. By identifying the greening mobility necessities, this research concludes on proposing a greening mobility framework to "clean" transportation and support the global vision to accommodate seamless, efficient, personalized and user friendly travel services and promote sustainable travel options.	
Keywords:	Clean transport, electric vehicles, greening mobility

Table 2: Paper P2 – Designing a Vissim-Model for a motorway network with systematic calibration on the basis of travel time measurements

Paper code:	**P2**
Responsible or involved partner:	UTH
Paper title:	Designing a Vissim-model for a motorway network with systematic calibration on the basis of travel time measurements
Author(s):	Ioannis Karakikes, Matthias Spangler, Martin Margreiter
Reference:	Karakikes, I., Spangler, M. & Margeiter, M., 2016. "Designing a Vissim-Model for a Motorway Network with Systematic Calibration on the Basis of

	Travel Time Measurements”. 3rd Conference on Sustainable Urban Mobility, Volos, Greece, 26-27 May 2016.
Abstract: This paper describes a systematic calibration process of a motorway network in Vissim, based on travel time measurements that were derived from limited number of Bluetooth detectors. The case study that is developed, establishes an example for practitioners that are interested in designing motorway networks with microscopic simulation tools. The three-hour microscopic traffic simulation model that will be analyzed, replicates a motorway network which is located in the wider area of Bavaria in Germany and consists of 500 links, 113 nodes and 1820 origin-destination pairs. Model’s systematic calibration and validation under the suggested approach show very good results in 96.5 % of the created intervals, for both cars and heavy vehicles.	
Keywords:	Vissim model, systematic calibration, motorway network, simulation

Table 3: Paper P3 – Assessing the performance of intermodal city logistics terminals in Thessaloniki

Paper code:	**P3**
Responsible or involved partner:	UTH
Paper title:	Assessing the performance of intermodal city logistics terminals in Thessaloniki
Author(s):	Eftihia Nathanail, Michael Gogas, Giannis Adamos
Reference:	Nathanail, E., Gogas, M. & Adamos, G., 2016. “Assessing the performance of intermodal city logistics terminals in Thessaloniki”. 3rd Conference on Sustainable Urban Mobility, Volos, Greece, 26-27 May 2016.
Abstract: The purpose of this paper is to present a comparative analysis of two urban intermodal freight transport terminals focusing on last mile distribution; the port of Thessaloniki (ThPA) and Kuehne + Nagel (K+N) distribution center. The paper enables the pairwise comparison of different intermodal freight transport nodes acting as interchanges in a supply chain with a special focus on the last mile distribution. The final outcome of the analysis is the creation of an auxiliary or subsidiary tool addressed to potential decision makers (e.g. shippers, forwarders, transport companies, users or customers of the two terminals within the supply chain). The evaluation of the terminals’ performance is elaborated based on a tailored multi criteria key performance indicator KPI-based assessment framework, while the selection and significance (weight) of the incorporated criteria and KPI’s is predetermined by the involved stakeholders imposing their point of view through an analytical hierarchy method. ThPA terminal was ranked first according to its performance pertaining to the role of an intermodal interchange, however K+N terminal’s performance index was slightly lower, while in several KPIs and criteria it seemed to perform better.	
Keywords:	City logistics, multi-stakeholder, multi-criteria evaluation framework, key performance indicators, comparative indices, sensitivity analysis, AHP, PROMETHEE, GAIA

Table 4: Paper P4 – Review of intelligent transport solutions in Latvia

Paper code:	**P4**
Responsible or involved partner:	TTI
Paper title:	Review of intelligent transport solutions in Latvia
Author(s):	Irina Yatskiv (Jackiva), Mihails Savrasovs, Dagnija Udre, Roberta Ruggeri
Reference:	Yatskiv (Jackiva), I., Savrasovs, M., Udre, D. & Ruggeri, R., 2016. "Review of intelligent transport solutions in Latvia". 3rd Conference on Sustainable Urban Mobility, Volos, Greece, 26-27 May 2016.
Abstract: The goal of the following paper is to make a review of existing intelligent transport solutions in Latvia. The results of the review were part of the RITS-NET project, implemented in frame of INTERREG IVC programme by consortium of partners from 9 EU countries, including Latvia. The project aims at enhancing regional sustainable transport policies via an increased knowledge and understanding of the full potential of Intelligent Transport Systems (ITS) solutions and ways to deploy them. To reach the goal the state-of-the-art of intelligent transport solutions in Latvia was completed, taking into account following subtopics: Emergency Management and Incident Services; ITS for Traffic Management and Mobility; Parking and Automatic Payment; ITS for Public Transport Management; Fleet Management and Freight. On each subtopic the careful review of existing solutions were completed and described.	
Keywords:	Intelligent transport solutions, state-of-the-art, sustainable transport networks, Latvia

Table 5: Paper P5 – A comprehensive analysis of the planned multimodal public transportation HUB

Paper code:	**P5**
Responsible or involved partner:	TTI
Paper title:	A comprehensive analysis of the planned multimodal public transportation HUB
Author(s):	Irina Yatskiv (Jackiva), Evelina Budilovich
Reference:	Yatskiv (Jackiva), I. & Budilovich, E., 2016. "A comprehensive analysis of the planned multimodal public transportation HUB". 3rd Conference on Sustainable Urban Mobility, Volos, Greece, 26-27 May 2016.
Abstract: The research interest in multi-modal passenger transportation planning is growing and dealing with transport infrastructure projects a big number of different challenges have to be considered. Urban transport planning includes scientific and technical knowledge to actions in urban space. In recent years a lot of smart technologies have been promoted for urban problems solving.	

However, the European Regulation No 1315/2013 takes account of the fact that infrastructure projects need a certain involvement of public and private stakeholders to ensure the promotion of sustainable transport solutions, such as enhanced accessibility by public transport, telematics applications, intermodal terminals/multimodal transport chains, low-carbon and other innovative transport solutions and environmental improvements and the enhancement of cooperation between the different stakeholders. So, including the transport sustainability issues (such as network efficiency, cohesion and environment) in planning process is the obligate requirement for strategic transport planning. The research presents an overview of the case study: planning decisions for the passenger network in Riga City in the frame of the Rail Baltic project – Riga central multimodal public transportation hub. Multi-modal transportation planning should have integrated institutions, networks, stations, user information, and fare payment systems; it is needed to consider all significant impacts, including long-term, indirect and non-market impacts such as equity and land use changes. One of the key-stone question in this case study - multi-modal transportation planning requires consideration of the factors that affect accessibility and whether they are currently considered in planning? The paper presents an integrated analysis in the area of planned transport node compiled from the individual partial studies and based on the desk research. Traffic on macro-level and transit mobility issues are the central aspect in this analysis.	
Keywords:	Sustainable development, multimodal transportation, terminal, planning, accessibility, indicator

Table 6: Paper P6 – Optimization of ground vehicle movement at aerodromes

Paper code:	**P6**
Responsible or involved partner:	TTI
Paper title:	Optimization of ground vehicle movement at aerodromes
Author(s):	Iyad Alomar, Jurijs Tolujevs
Reference:	Alomar, I. & Tolujevs, J., 2016. “Optimization of ground vehicle movement at aerodromes”. 3rd Conference on Sustainable Urban Mobility, Volos, Greece, 26-27 May 2016.
Abstract: This paper deals with the process of management of ground vehicle movement at aerodromes. It is a huge challenge to provide the growth of airport capacity which is required due to the increasing number of passengers and goods flow, without good management in aircraft operations, including the standing time of aircraft on the ground. In the first part of this Article, the current trends in the development of airport ground processes and control techniques are considered. Official IATA (International Air Transport Association) documents and scientific publications are the source of new ideas in this field. In the second part of this Article, the use of computer simulation is prescribed for the purpose of testing new methods of transport movement control. Also, the methodology of the simulation model, which has been designed to optimize work flows arising during movements of airport ground vehicles, is demonstrated. The developed model is a test bed for conducting experiments, which may help in finding more effective airport ground processes control techniques. A similar model can be created for any other airport, on the basis of which is scheduled to verify the possibility of technical implementation of new control	

technologies of ground vehicles. The practical implementation of these new technologies should be solved taking into account the requirements of ICAO and IATA, in particular ICAO Annex 14.	
Keywords:	A-SNGCS, airport movement area, ground handling, optimization, simulation

Table 7: Paper P7 – A fuzzy and a Monte Carlo simulation approach to assess sustainability and rank vehicles in urban environment

Paper code:	**P7**
Responsible or involved partner:	UTH
Paper title:	A fuzzy and a Monte Carlo simulation approach to assess sustainability and rank vehicles in urban environment
Author(s):	Lambros K. Mitropoulos, Panos D. Prevedouros, Xin (Alyx) Yu, Eftihia G. Nathanail
Reference:	Mitropoulos, L., Prevedouros, P., Yu, X. & Nathanail, E., 2016. "A fuzzy and a Monte Carlo simulation approach to assess sustainability and rank vehicles in urban environment". 3rd Conference on Sustainable Urban Mobility, Volos, Greece, 26-27 May 2016.
Abstract: The technological differences among conventional, hybrid and alternative fuel vehicles and buses, the large number of variables in the sustainability assessment of transportation systems and the subjective judgment of decision makers introduce uncertainty. The objectives of this paper are to develop and present a fuzzy and a Monte Carlo Simulation (MCS) approach for the sustainability assessment of urban transportation vehicles and evaluate the applicability of the methods to selected indicators for ranking the sustainability performance of vehicles. The fuzzy method provided vehicle rankings on a continuous scale and integrate vehicle technology and fuel characteristics in the assessment, whereas the MCS generated a range of outputs in a probability distribution to represent the uncertainty associated with data collection and sustainability indicators.	
Keywords:	Vehicle technology, uncertainty, fuzzy methods, Monte Carlo

Table 8: Paper P8 – Analysis of impacts of the Rail Baltica project: cargo multimodal hubs development

Paper code:	**P8**
Responsible or involved partner:	TTI
Paper title:	Analysis of impacts of the Rail Baltica project: cargo multimodal hubs development
Author(s):	Denis Ravtsov, Irina Yatskiv (Jackiva)

Reference:	Ravtsov, D. & Yatskiv (Jackiva), I., 2016. "Analysis of impacts of the Rail Baltica project: cargo multimodal hubs development". 3rd Conference on Sustainable Urban Mobility, Volos, Greece, 26-27 May 2016.

Abstract:

The development of the Rail Baltica project is significant in light of implementing the EU Strategy for Baltic Sea Region and in case of a successful project implementation high quality rail connection between the Baltic States and the biggest economic, administrative and culture centers of Western Europe will be ensured. The main objective of this project is to establish a more solid link with the European central areas thus contributing to mutually beneficial cooperation. Research goal is the analysis of project impact on cargo flows in Baltic Sea Region and possibility of hub formation at the intersection of two types of railways – "eastern" and "western". In order to perform a comprehensive current situation analysis and future development assessment for the Rail Baltica project at first the list of stakeholders was recognized. A review and analysis of official forecasts about possible increase of cargo flows, including transit, is considered. Nuanced discussion has been raised about types of shipments in transit, expected cargo turnover and forecast about types of shipments imported or exported from Latvia or handled by Latvian logistics operators. On the basis of such analysis authors consider the locations, where multimodal cargo hub in Latvia could be implemented.

Keywords:	Rail Baltica, cargo flows, multimodal hub, project impacts, location problem

Table 9: Paper P9 – Broadcast transponders for low flying aerial vehicles

Paper code:	**P9**
Responsible or involved partner:	TTI
Paper title:	Broadcast transponders for low flying aerial vehicles
Author(s):	Dmitrijs Lancovs
Reference:	Lancovs, D., 2016. "Broadcast transponders for low flying aerial vehicles". 3rd Conference on Sustainable Urban Mobility, Volos, Greece, 26-27 May 2016.

Abstract:

Present day unmanned aerial vehicle (UAV) technology in urban mobility applications is severely limited in use due to lack of reliable collision avoidance mechanisms. There are numerous applications for UAVs in urban environments, including information awareness, urban management, on-demand goods deliveries, and even parking assist, but present day legal regulations preclude their use over safety concerns, requiring presence of a pilot and restricting UAV use in urban areas.

Indeed, possibility of midair collision is a significant concern in a densely populated urban area, and will only get worse as UAV use becomes widespread.

Collision avoidance cannot be done effectively using onboard sensors. A transponder system like automatic dependent surveillance-broadcast (ADS-B) could be used to augment airspace awareness of UAVs, greatly reducing collision risks.

SPH Engineering has successfully integrated such transponders with two of the most popular consumer class autopilots. In each case a device by Sagetech was used, the smallest commercially available transponder to date. This is a major step towards commercial UAV integration into regulated airspace. Unfortunately, ADS-B is ill suited for small low flying UAVs that are navigating unregulated airspace. While weight and power are the more obvious limitations, the use of ADS-B also requires International Civil Aviation Organization (ICAO) certification, which is both expensive and lengthy. Furthermore, at close range receiver was overwhelmed by transmit power. In a collision avoidance scenario for delivery drones short range is exactly where reliable reception is most needed. This article presents an approach, which is used to design a collision avoidance system in accordance with safety regulations of manned aviation that would be specific to small, commercial UAVs operating in unregulated airspace.

Keywords:	UAV, collision avoidance, cooperative, infrastructure-independent

Table 10: Paper P10 – The linkage among social networks, travel behaviour and spatial configuration

Paper code:	**P10**
Responsible or involved partner:	UTH
Paper title:	The linkage among social networks, travel behavior and spatial configuration
Author(s):	Pnina Plaut, Eftihia Nathanail
Reference:	Plaut, P. & Nathanail, E., 2016. "The linkage among social networks, travel behavior and spatial configuration". 3rd Conference on Sustainable Urban Mobility, Volos, Greece, 26-27 May 2016.

Abstract:

Social Travel Behavior (STB) is an emerging research field that seeks to analyze travel patterns as derived from social structures, for example, online social networks. As a result of rapid advances in Information and Communications Technology (ICT) over the past decade, social networks have begun to morph away from traditional structures into new alternative dynamic ones, such as those based upon internet relationships. An enormous amount of human capital is now invested in social networking sites (SNS), most notably Facebook. Each online social network encompasses social capital composed of weak and strong ties and a large and heterogeneous stock of information, some of which carries spatial context and implications.

Keywords:	Travel behavior, ICT, social networks, survey, event

Table 11: Paper P11 – Enhancing sustainable mobility: A business model for the port of Volos

Paper code:	**P11**
Responsible or involved partner:	UTH
Paper title:	Enhancing sustainable mobility: A business model of the port of Volos
Author(s):	Vissarion Manginas, Stefania Manoli, Eftihia Nathanail
Reference:	Manginas, V., Manoli, S. & Nathanail, E., 2016. "Enhancing sustainable mobility: A business model of the port of Volos". 3rd Conference on Sustainable Urban Mobility, Volos, Greece, 26-27 May 2016.

Abstract:

The current paper concerns the investigation of the possibility of implementing Public Private Partnership (PPP) in the Port of Volos and eventually, the development of a business model supporting it.

For this purpose, extensive literature research was acquired, in order to fully comprehend the organizational schemes and state of practice of PPPs, their general features, as well as assess their efficiency in certain port functions and services. At the same time, the corresponding legal and policy frameworks were also studied, applying in international and Greek case studies.

Additional research was conducted, aiming at the functions of the organization, where a private involvement would potentially benefit the organization itself, as well as the rest of the stakeholders. This part of the research included interviews with key staff of the Volos Port Authority and local travel and port agents and the completion of survey questionnaires by a random sample of 100 passengers, during afternoon hours. The interviews were focused mainly on the Port Authority's operation, while the questionnaires were focused on the port infrastructure, the provided services and the satisfaction of the passengers in regard to these factors.

The collected data were analyzed, using a modified version of Analytic Hierarchy Process (AHP) to decide the importance of certain port functions and services. Subsequently, three possible ownership models were formulated. The proposed models were the current one, a landlord model and a combination of the current one with some level of privatization of port services or facilities. Based on literature research, their effectiveness on selected port functions and services was evaluated.

The results of the aforementioned process indicated, that the landlord ownership model would be the most effective for the particular case of Volos Port Authority, followed by full privatization, with the current model as a close third possibility. More specifically, the landlord model seemed to perform better in improving both the operation of the organization and the level of passenger satisfaction, through its increased flexibility, the possible segmentation of services, increased capital investment and a reduction of bureaucracy. Using these results, a business model was formulated, based on the Business Model Canvas.

Keywords:	Public-Private-Partnership, privatization, business model, port of Volos

3 Analysis of the submitted papers

Figure 1 shows the distribution of the submitted papers into the Conferences' thematic areas. It is indicated that TTI and UTH staff covered almost all of the areas (8 out of 11) with at least one paper, while for "Transportation Interchanges" and "City Logistics (including conferences' NOVELOG 'City Logistics in an era of change' special session") two and three papers were submitted, respectively.

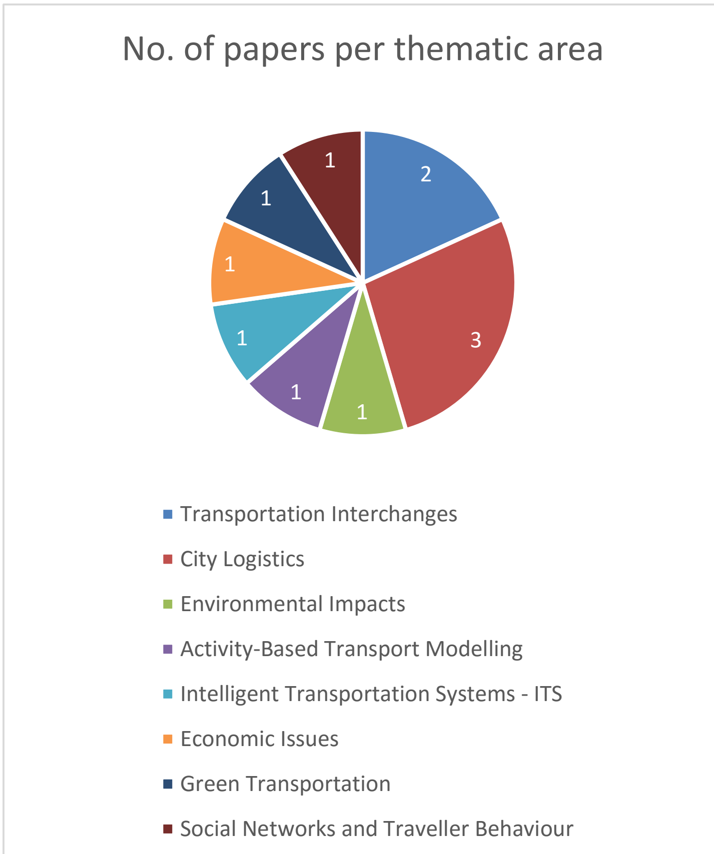

Figure 1: Number of papers per thematic area

Regarding the number of papers submitted per country, five out of eleven papers were prepared by TTI staff from Latvia and the rest six papers by the UTH staff from Greece (Figure 2).

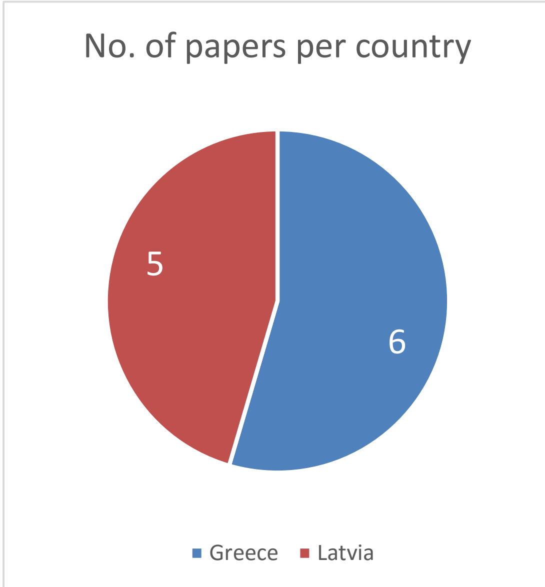

Figure 2: Number of papers per country

In addition, the 46% of the authors or co-authors of the papers were women, and the rest 54% were men, showing a very good gender balance (Figure 3).

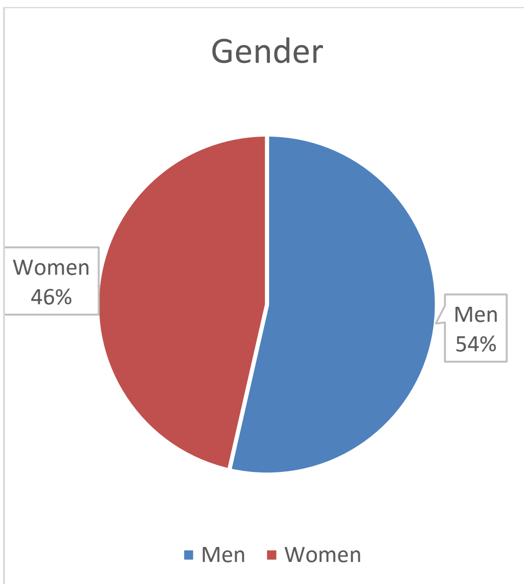

Figure 3: Gender distribution

Lastly, 52% of the authors or co-authors were young researchers and the rest 48% were senior researchers, addressing the scope of ALLIANCE for the active involvement of students and young researchers in its activities (Figure 4).

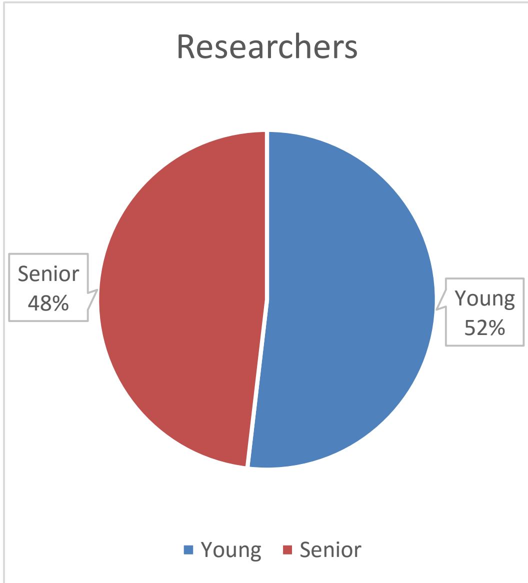

Figure 4: Percentage of young & senior researchers

4 Synopsis

This deliverable is the compendium of the ALLIANCE's contribution to the 3rd Conference on Sustainable Urban Mobility (3rd CSUM) which was held on 26 – 27 May, 2016 in Volos, Greece.

Eleven papers from TTI and UTH staff were submitted to the Conference and an overview of the activity and the papers is presented in Tables 12 and 13, respectively.

Table 12: Overview of the activity

No.	Type of activity	Main Leader	Title	Date/period	Place	Type of audience	Size of audience	Countries addressed
1	International Conference	UTH	3rd Conference on Sustainable Urban Mobility	26 – 27 May, 2016	Volos, Greece	Research & academics communities, Local & regional authorities, Transport & terminal operators, Transport policy makers & influencers, Enterprises /Businesses, General public	120 participants	20

Table 13: Overview of the papers

No.	Title	Authors	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers (e.g.. link, if available)	Is/Will open access provided to this publication?
1	A “Greening Mobility” Framework Towards Sustainability	Evangelos Bekiaris, Maria Tsami	Compendium of papers presented at the International Conference of Sustainable Urban Mobility 2016	June 2016	ALLIANCE Project	Volos, Greece	2016	-	www.alliance-project.eu/deliverables/	Yes
2	Designing a Vissim-Model for a Motorway Network with Systematic Calibration on the Basis of Travel Time Measurements	Ioannis Karakikes, Matthias Spangler, Martin Margreiter	Compendium of papers presented at the International Conference of Sustainable Urban Mobility 2016	June 2016	ALLIANCE Project	Volos, Greece	2016	-	www.alliance-project.eu/deliverables/	Yes
3	Assessing the performance of intermodal city logistics terminals in Thessaloniki	Efthihia Nathanail, Michael Gogas, Giannis Adamos	Compendium of papers presented at the International Conference of Sustainable Urban Mobility 2016	June 2016	ALLIANCE Project	Volos, Greece	2016	-	www.alliance-project.eu/deliverables/	Yes
4	Review of intelligent transport solutions in Latvia	Irina Yatskiv (Jackiva), Mihails Savrasovs, Dagnija Udre,	Compendium of papers presented at the International Conference of Sustainable	June 2016	ALLIANCE Project	Volos, Greece	2016	-	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	Relevant pages	Permanent identifiers (e.g.. link, if available)	Is/Will open access provided to this publication?
		Roberta Ruggeri	Urban Mobility 2016							
5	A Comprehensive Analysis of the Planned Multimodal Public Transportation HUB	Irina Yatskiv (Jackiva), Evelina Budilovich	Compendium of papers presented at the International Conference of Sustainable Urban Mobility 2016	June 2016	ALLIANCE Project	Volos, Greece	2016	-	www.alliance-project.eu/deliverables/	Yes
6	Optimization of Ground Vehicle Movement at Aerodromes	Iyad Alomar, Jurijs Tolujevs	Compendium of papers presented at the International Conference of Sustainable Urban Mobility 2016	June 2016	ALLIANCE Project	Volos, Greece	2016	-	www.alliance-project.eu/deliverables/	Yes
7	A Fuzzy and a Monte Carlo Simulation Approach to Assess Sustainability and Rank Vehicles in Urban Environment	Lambros K. Mitropoulos, Panos D. Prevedouros, Xin (Alyx) Yu, Eftihia G. Nathanail	Compendium of papers presented at the International Conference of Sustainable Urban Mobility 2016	June 2016	ALLIANCE Project	Volos, Greece	2016	-	www.alliance-project.eu/deliverables/	Yes
8	Analysis of impacts of the Rail Baltica project: cargo multimodal hubs development	Denis Ravtsov, Irina Yatskiv (Jackiva)	Compendium of papers presented at the International Conference of Sustainable	June 2016	ALLIANCE Project	Volos, Greece	2016	-	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	Relevant pages	Permanent identifiers (e.g.. link, if available)	Is/Will open access provided to this publication?
			Urban Mobility 2016							
9	Broadcast transponders for low flying unmanned aerial vehicles	Dmitrijs Lancovs	Compendium of papers presented at the International Conference of Sustainable Urban Mobility 2016	June 2016	ALLIANCE Project	Volos, Greece	2016	-	www.alliance-project.eu/deliverables/	Yes
10	The linkage among social networks, travel behavior and spatial configuration	Pnina Plaut, Eftihia Nathanail	Compendium of papers presented at the International Conference of Sustainable Urban Mobility 2016	June 2016	ALLIANCE Project	Volos, Greece	2016	-	www.alliance-project.eu/deliverables/	Yes
11	Enhancing sustainable mobility: A business model for the port of Volos	Vissarion Manginas, Stefania Manoli, Eftihia Nathanail	Compendium of papers presented at the International Conference of Sustainable Urban Mobility 2016	June 2016	ALLIANCE Project	Volos, Greece	2016	-	www.alliance-project.eu/deliverables/	Yes

Annexes

Annex A: Conference’s programme
Annex B: Full papers

Annex A

3rd Conference on Sustainable Urban Mobility (3rd CSUM)

http://www.csum.civ.uth.gr/

@ Room "Iolkos"
Valis Resort Hotel, Stathmos Agrias, Volos, Greece
Thursday 26 May, 2016

Programme

09:30 – 10:15 Registration

10:15 – 10:30 Opening

10:30 – 13:00	**Special Session: COST TU1305 'Social networks and travel behavior'**	*Moderator: Domokos Esztergár-Kiss*

- **The linkage among social networks, travel behavior and spatial configuration** – Pnina Plaut, Eftihia Nathanail
- **Electric bikes usage potential as a substitute for private car usage in Israel** – Or Caspi
- **An agent-based pedestrian model considering spatial behavior parameters** – Itzhak Omer, Nir Kaplan
- **Sustainability analysis on urban mobility based on social media content** – Ainhoa Serna, Jon Kepa Gerrikagoitia, Unai Bernabé, Tomás Ruíz
- **Definition and classification of parameters for daily activity chain optimization** – Domokos Esztergár-Kiss
- **The relation between travel behavior, ICT usage and social networks. The design of a web based survey** – João de Abreu e Silva, Juan de Oña, Slaven Gasparovic

13:00 – 14:00 Lunch

14:00 – 16:00	**Special Session: NOVELOG 'City Logistics in an era of change'**	*Moderator: Peter Koenig*

- **Smart urban freight transport in the city of Graz** – Gerhard Ablasser, Peter Koenig
- **Integrated freight 'door-to-door' services and cargo consolidation in Athens** – Sofia Bouki
- **Assessing the performance of intermodal city logistics terminals in Thessaloniki** – Eftihia Nathanail, Michael Gogas, Giannis Adamos
- **From gentle mobility to smart city** – Gerhard Ablasser
- **SUMP and DOT (demand orientated transport) for leisure sites - an antipode?** – Peter Koenig

16:00 – 16:15 Coffee Break

16:15 – 18:00	**Session: Transportation Interchanges**	*Moderator: Gerhard Ablasser*

- **Sustainable mobility in small towns like Xanthi** – Konstantina Lantitsou, Vasilis Profillidis, Giorgos Kollaros
- **Multi-criteria evaluation of public transport interchanges** – Zofia Bryniarska, Lidia Zakowska
- **Review of intelligent transport solutions in Latvia** – Mihails Savrasovs, Roberta Ruggeri, Irina Yatskiv, Dagnija Udre
- **Small scale intervention in a major city center interchange. Economic, environmental and sustainability analysis** – Aristomenis Kopsacheilis, Giorgos Barmpas, Ioannis Politis
- **A comprehensive analysis of planned multimodal public transportation HUB** – Irina Yatskiv (Jackiva), Evelina Budilovich

18:00 – 19:40	**Session: Activity-Based Transport Modelling**	*Moderator: Itzhak Omer*

- **Optimization of ground vehicle movement at aerodromes** – Iyad Alomar, Jurijs Tolujevs
- **Green transport in island areas: lessons learned from North Aegean** – Ioannis Tsouros, Amalia Polydoropoulou
- **Gravity vs radiation model: two approaches on commuting in Greece** – Maria Stefanouli, Serafeim Polyzos
- **The urban project of HafenCity. Presentation, targets, goals and original applications of the surrounding area, through the pilot use of a set of indicators of the "European Local Transport Information Service (ELTIS)"** – Eleftheriou Vasileios, Jörg Knieling

21:00 Dinner @ Agraia Restaurant – Hotel Valis

END OF DAY 1

3[rd] Conference on Sustainable Urban Mobility
(3[rd] CSUM)

http://www.csum.civ.uth.gr/

@ Room "Pelion"
Valis Resort Hotel, Stathmos Agrias, Volos, Greece
Thursday 26 May, 2016

Programme

09:30 – 10:15 Registration

10:15 – 10:30 Opening

10:30 – 13:00	Session: Green Transportation	*Moderator: Evangelos Bekiaris*

- **A "Greening Mobility" framework towards sustainability –** Maria Tsami, Evangelos Bekiaris
- **The bicycle as a means of ecological, social and economic sustainable mobility –** Eleni Linaki, Maria Lydia Mitritsa, Maria Sifnaiou
- **Cycling: utilitarian and symbolic dimensions –** Eleni Lourontzi, Stiliani Petachti
- **Micro and macro modelling approaches for the evaluation of the carbon impacts from transportation –** Silvio Nocera, Matteo Basso, Federico Cavallaro
- **Framework of monitoring urban mobility in European cities –** Aba Attila, Fleischer Tamás, Kukely György
- **Smart mobility and smart environment in the Spanish cities –** Neus Baucells Aletà, Concepción Moreno Alonso, Rosa M. Arce Ruiz

13:00 – 14:00 Lunch

14:00 – 16:00	Session: Social Networks & Traveller Behavior	*Moderator: Eftihia Nathanail*

- **Sustainable mobility and physical exercise: a meaningful marriage –** Pantoleon Skayannis, Marios Goudas, Petros Rodakinias
- **Context-driven regret-based model of travel behavior under uncertainty: a latent class approach –** Eleni Charoniti, Soora Rasouli, Harry Timmermans
- **City sustainability: the influence of walkability on built environments –** Reihaneh Rafiemanzelat, Aida Jalal Kamali, Maryam Imani Emadi
- **The effect of major market and societal trends on public transport in European cities –** Margarita Angelidou, Evangelos Genitsaris, El Aissati Hafieda, Aristotelis Naniopoulos
- **iTrip, a framework to enhance urban mobility by leveraging various data sources –** Praboda Rajapaksha, Reza Farahbakhsh, Eftihia Nathanail, Noel Crespi
- **Factors affecting the propensity to cycle - the case of Thessaloniki –** Ioanna Spyropoulou, Maria Konstantinidou

16:00 – 16:15 Coffee Break

16:15 – 18:00	Session: Intelligent Transportation Systems - ITS	*Moderator: Slaven Gasparovic*

- **Designing a Vissim-model for a motorway network with systematic calibration on the basis of travel time measurements –** Ioannis Karakikes, Matthias Spangler, Martin Margreiter
- **Semantic integration of urban mobility data for supporting visualization –** Thiago Sobral, Teresa Galvão, José Borges
- **Evaluation of an integrated mobile payment, route planner and social network solution for public transport –** Marta Campos Ferreira, Tânia Fontes, Vera Costa, Teresa Galvão Dias, José Luís Borges, João Falcão e Cunha
- **Elderly and infomobility services: late bloomers or technology left-outs? –** Iraklis Stamos, George Giannopoulos, Georgia Aifadopoulou, Evangelos Bekiaris, Maria Panou, Katerina Touliou, Evangelos Mitsakis, Josep Maria Salanova Grau
- **The importance of intelligent transport systems in the preservation of the environment and reduction of harmful gases –** Firas Th. Alrawi, Seda S. Mesrob

18:00 – 19:40	Session: Safety & Security I	*Moderator: Athanasios Galanis*

- **Bluetooth-based travel times for Automatic Incident Detection – A systematic description of the characteristics for traffic management purposes –** Maria Karatsoli, Martin Margreiter, Matthias Spangler
- **Identification of quality indexes in school bus transportation system –** Kornilia Maria Kotoula, Aggeliki Sakellariou, Maria Morfoulaki, Georgios Mintsis
- **Pedestrian road safety in relation to urban road type and traffic flow –** Athanasios Galanis, George Botzoris, Nikolaos Eliou
- **Road safety in urban areas in Greece during economy downturn. A before – after comparison –** Pantelis Kopelias, Mpogas Konstantinos, Lambros Mitropoulos, Konstantinos Kepaptsoglou
- **A review of resilience management applications in the transport sector –** Evangelia Gaitanidou, Maria Tsami, Evangelos Bekiaris

21:00 Dinner @ Agraia Restaurant – Hotel Valis

END OF DAY 1

3rd Conference on Sustainable Urban Mobility (3rd CSUM)

http://www.csum.civ.uth.gr/

@ Room "Iolkos"
Valis Resort Hotel, Stathmos Agrias, Volos, Greece
Friday 27 May, 2016

Programme

09:00 – 11:00	**Session: Economic Issues**	*Moderator: Vassilios Profillidis*

- **Economic crisis and promotion of sustainable transportation: a case survey in the city of Volos, Greece** – Athanasios Galanis, George Botzoris, Anastasios Siapos, Nikolaos Eliou, Vassilios Profillidis
- **Assessment of the marginal social cost due to congestion using the speed flow function** – Anastasios Tsakalidis, Nikolaos Gavanas, Magda Pitsiava-Latinopoulou
- **Car dealerships and their role in electric vehicles market penetration: a Greek market case study** – Alkiviadis Tromaras, Aggelos Aggelakakis, Dimitris Margaritis
- **Total cost of ownership and externalities of electric, hybrid and conventional vehicle** – Lambros K. Mitropoulos, Panos D. Prevedouros, Pantelis Kopelias
- **Enhancing sustainable mobility: a business model for the port of Volos** – Vissarion Manginas, Stefania Manoli, Eftihia Nathanail

11:00 – 11:15 Coffee Break

11:15 – 13:15	**Session: Environmental Impacts I**	*Moderator: Lambros K. Mitropoulos*

- **Investigation of the users' acceptance concerning a Low Emission Zone in the center of Thessaloniki, Greece** – Sokratis Basbas, Nikolaos Sfendonis, Giorgos Mintsis, Christos Taxiltaris, Ioannis Politis
- **Traffic and environmental impacts of traffic incidents on Thessaloniki's inner ring road** – Eleni Karioti, Socrates Basbas, Evangelos Mintsis, Georgios Mintsis, Christos Taxiltaris
- **A Fuzzy and a Monte Carlo simulation approach to assess sustainability and rank vehicles in urban environment** – Lambros K. Mitropoulos, Panos D. Prevedouros, Xin (Alyx) Yu, Eftihia Nathanail
- **Sustainable urban mobility indicators: policy versus practice in the case of Greek cities** – Alexandros Sdoukopoulos, Pavlos Tafidis, Magda Pitsiava-Latinopoulou
- **Simulating traffic and environmental effects of pedestrianization and traffic management. A comparison between static and dynamic traffic assignment** – Lazaros Giannakos, Evangelos Mintsis, Socrates Basbas, George Mintsis, Christos Taxiltaris

13:15 – 14:15 Lunch

14:15 – 16:15	**Session: Environmental Impacts II**	*Moderator: Irina Kuzmina-Merlino*

- **Tackling mobility environmental impacts through the Promotion of student active travel** – Foteini Mikiki, Panagiota Papadopoulou
- **Evaluation of sustainable urban mobility in the city of Thessaloniki** – Vasiliki-Maria Perra, Alexandros Sdoukopoulos, Magda Pitsiava – Latinopoulou
- **Development and implementation of walkability audits in Greek medium-sized cities: the case of the Serres' city centre** – Alexandros Sdoukopoulos, Anastasios Tsakalidis, Eleni Verani, Anastasia Nikolaidou, Nikolaos Gavanas, Magda Pitsiava-Latinopoulou, Foteini Mikiki, Eleni Mademli, Christos Pallas
- **Four stories for sustainable mobility in Greece** – Charalampos Kyriakidis, Efthimios Bakogiannis, Maria Siti, Vasilios Eleftheriou
- **An integrated low-cost road traffic and air pollution monitoring platform for next citizen observatories** – Giovanni Gualtieri, Alessandro Zaldei, Francesca Camilli, Tiziana de Filippis, Filippo di Gennaro, Sara di Lonardo, Fabrizio Dini, Beniamino Gioli, Alessandro Matese, Walter Nunziati, Leandro Rocchi, Piero Toscano, Carolina Vagnoli

16:15 – 16:30 Coffee Break

16:30 – 18:30	**Session: City Logistics**	*Moderator: Irina Yatskiv*

- **Data collection framework for understanding UFT within city logistics solutions** – Andrea Campagna, Alexander Stathacopoulos, Luca Persia, Elpida Xenou
- **An advanced solution approach for energy efficient garbage collection service** – Afroditi Anagnostopoulou, Maria Boile, Evangelia Papargyri, Maria Poulou
- **Analysis of impacts of the Rail Baltica project: cargo multimodal hubs development** – Deniss Ravtsov (Ravcovs), Irina Yatskiv (Jackiva)
- **Broadcast transponders for low flying unmanned aerial vehicles** – Dmitrijs Lancovs

18:30 – 19:00 Closure

END OF DAY 2 – End of 3rd CSUM

3rd Conference on Sustainable Urban Mobility (3rd CSUM)

http://www.csum.civ.uth.gr/

@ Room "Pelion"
Valis Resort Hotel, Stathmos Agrias, Volos, Greece
Friday 27 May, 2016

Programme

09:00 – 11:00	**Session: Public Transport and Demand Responsive Systems I**	*Moderator: Athanasios Lois*

- **Online algorithm for dynamic dial a ride problem and its metrics** – Athanasios Lois, Athanasios Ziliaskopoulos
- **The existing school transportation framework in Greece** – Barriers and problems comparing to other European countries – Kornilia Maria Kotoula, George Botzoris, Maria Morfoulaki, Georgia Aifadopoulou
- **A methodological framework for assessing the success of Demand Responsive Transport (DRT) services** – Anestis Papanikolaou, Socrates Basbas, George Mintsis, Christos Taxiltaris
- **A hybrid approach to the problem of journey planning with the use of mathematical programming and modern techniques** – Georgios K.D. Saharidis, Dimitrios Rizopoulos, Afroditi Temourtzidou, Antonios Fragkogios, Nikolaos Cholevas, Asimina Galanou, George Emmanouelidis, Chrysostomos Chatzigeorgiou, Labros Bizas
- **Mobile payments adoption in public transport** – Tânia Fontes, Vera Costa, Marta Campos Ferreira, Li Shengxiao, Pengjun Zhao, Teresa Galvão Dias

11:00 – 11:15 Coffee Break

11:15 – 13:15	**Session: Public Transport and Demand Responsive Systems II**	*Moderator: Emy Apostolopoulou*

- **Towards promoting efficient BRT in Dhaka** – Salma Sultana, Mazharul Hoque, Shamima Nasrin
- **Urban sea transportation in Greece, the case of Skiathos** – Athanasios E. Zlatoudis
- **Investigating the preferences of students towards the creation of a carpooling system serving the academic bodies of Thessaloniki city** – Sofia Liakopoulou, Maria Mavromati Kakana, Panagiota Avtji, Evangelos Genitsaris, Aristotelis Naniopoulos
- **ID based ticketing and mobile tickets make Turku region public transport even more customer-friendly** – Sirpa Korte
- **Shifting towards mass rapid transit in the Maltese Islands** – Malcolm Cachia

13:15 – 14:15 Lunch

14:15 – 16:15	**Session: Safety & Security II**	*Moderator: Giannis Adamos*

- **Road signage comprehension and overload: the role of driving style and need for closure** – Shaun Bortei-Doku, Sigal Kaplan, Carlo Giacomo Prato, Otto Anker Nielsen
- **The concept of woonerf zone applied in university campuses: the case of the campus of the Aristotle University of Thessaloniki** – Dimitrios Nalmpantis, Aristotelis Naniopoulos, Sofia Christina Lampou
- **Static and dynamic resilience of transport infrastructure and demand: the case of the Athens metro** – Alexandros Deloukas, Emy Apostolopoulou
- **Artificial intelligence and crime prediction in public management of transportation safety in urban environment** – Georgios N. Kouziokas
- **Car-pedestrian and car-cyclist accidents in Hungary** – Attila Glász, János Juhász

16:15 – 16:30 Coffee Break

16:30 – 18:30	**Session: Accessibility Analysis**	*Moderator: Serafeim Polyzos*

- **The topology of urban road networks and its role to urban mobility** – Dimitrios Tsiotas, Serafeim Polyzos
- **A new anthropocentric approach in accessibility analysis: the activity space and the accessibility measures** – Fotini Moustou
- **Accessibility assessment of urban mobility: the case of Volos, Greece** – Dimitrios Tsiotas, Olga Kalantzi, Ioannis Gavardinas
- **What matters when it comes to "Walk and the City"? Defining a weighted GIS-based walkability index** – Alexandros Bartzokas Tsiompras, Yorgos N. Photis
- **Transforming small towns by remedial street design** – Fotini Kehagia

18:30 – 19:00 Closure

END OF DAY 2 – End of 3rd CSUM

Annex B

Paper code	Title of Papers
P1	A “Greening Mobility” framework towards sustainability
P2	Designing a Vissim-Model for a Motorway Network with Systematic Calibration on the Basis of Travel Time Measurements
P3	Assessing the performance of intermodal city logistics terminals in Thessaloniki
P4	Review of intelligent transport solutions in Latvia
P5	A comprehensive analysis of the planned multimodal public transportation HUB
P6	Optimization of ground vehicle movement at aerodromes
P7	A fuzzy and a Monte Carlo simulation approach to assess sustainability and rank vehicles in urban environment
P8	Analysis of impacts of the Rail Baltica project: cargo multimodal hubs development
P9	Broadcast transponders for low flying aerial vehicles
P10	The linkage among social networks, travel behaviour and spatial
P11	Enhancing sustainable mobility: A business model for the port of Volos

3rd Conference on Sustainable Urban Mobility, 3rd CSUM 2016, 26 – 27 May 2016, Volos, Greece

A “Greening Mobility” Framework Towards Sustainability

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Abstract

In terms of the present paper, the clean vehicles vision, operation and necessity are being discussed pointing out the need to raise awareness to citizens and keep them informed about the potentials of newer technologies and clean vehicle usage. The approach is based on a concise analysis of the current policies and applications, examining a number of case studies that can be considered as coming close to the notion of “green mobility” and are treated as best practices. By identifying the greening mobility necessities, this research concludes on proposing a greening mobility framework to “clean” transportation and support the global vision to accommodate seamless, efficient, personalized and user friendly travel services and promote sustainable travel options.

Keywords: clean transport, Electric Vehicles, greening mobility

1. Introduction

Transportation seems to be the key area of intervention in order to improve fuel quality and reduce greenhouse gas emissions considering that the EU target is to reduce these emissions by 80% till 2050. Greening mobility is therefore the ultimate transport challenge towards sustainability while it is labeled green, inlying that will

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significantly reduce greenhouse gas emissions. Facing this global sustainability challenge arises the need to adopt an environmental friendly mobility culture by using new technologies and fuel options.

The approach followed in terms of the present paper is based on a concise analysis of the current studies, policies and applications with emphasis on examining a number of case studies that can be considered as coming close to the notion of “green mobility” and are treated as best practices. Based on the state-of the art review and the future mobility challenges, we underline the Greening Mobility Necessities (GMN) of the future sustainable transport environment. GMNs frame the proposed Greening Mobility Framework (GMF) that aims to “clean” transportation by providing strategic guidance to create an informed public that is positively disposed to EVs.

2. Background

Electrification of road transport has become a major trend (Dijk et al. 2013) and Electric Vehicles (EVs) are becoming increasingly widespread (Al-Alawi and Bradley, 2013; U.S. Department of Energy, 2015). EVs contribute on reducing transport pollutants, having greater efficiency of the prime mover and enabling significant benefits in an urban mobility context (with low vehicle speeds, low power requirement, short trips). Bekiaris and Tsami (2015) stated that “Electric vehicles can significantly reduce global and local emissions and are part of the future vision for global mobility, not only for the reduction of CO2 emissions and elimination of greenhouse gas but also for their potential to accommodate seamless, efficient, personalized and user friendly travel services and to raise awareness for sustainable travel options and lifestyle. We need to think for the future and open ground to cleaner travel options”. EVs hold the potential to reduce oil dependency and decarbonize road transport (Department of Energy and Climate Change, 2013) and are the main contributors on the development of a Greening Mobility era of transport towards sustainability.

A lot of research has been made on EVs awareness and usage. Bunce et al (2014) conducted research to investigate responses of EV drivers in UK to recharging plug-in battery electric vehicles. Responders assessed their attitudes and experiences before they obtained their EV and after driving the EV for 3 months. This research underlined an interesting difference in drivers’ awareness of the environmental impact of driving and recharging an EV before and after the trial in relation to CO_2 emissions and the energy cycle.

Research has also been conducted in the field of examining attitudes and perceptions towards EVs amongst potential buyers. In a recent study conducted in the US (Krause et al., 2013) urban resident drivers were questioned about their knowledge of EVs. The results shown a high number of misconceptions over operating costs, recharging time, purchase price and driving range. Moreover, the majority of the sample (70%) underestimated the extent of fuel savings. In a similar survey conducted in UK, over 70% of participants perceived an inconvenience on recharging the car and felt threatened by the possibility not to be able to cover the required travel distances with an EV. (Smart, 2010). Similar findings have been found in Sweden (Gärling, 2001) and Belgium (Lebeau et al., 2013) about recharging time along with financial cost of electricity, and driving range. On the other hand, EV drivers point out the advantages of powering an EV over refuelling conventional vehicles and cost savings of EVs powering (Graham-Rowe et al., 2012; Kurani et al., 2008). The Smart survey (2010) shown that potential EV consumers are willing to buy an EV if only the public charging infrastructure was improved and underlined the necessity for local councils to invest in infrastructure.

Recently many countries have adopted policies (i.e. tax incentives for the purchase), to increase electromobility, aiming to eliminate pollutant emissions from traffic and improve the air quality, especially in urban areas (Ferrero et.al., 2016).

EVs can help to reduce transport emissions; however, the user behavior has a significant impact on energy savings. Franke et.al. (2016), conducted research on ecodriving EVs, aiming to understand EV drivers' ecodriving strategies along with the potential challenges for optimal user - energy interaction. Ecodriving aims at optimizing energy efficiency (McIlroy and Stanton, 2015; Stillwater and Kurani, 2013) and thus changing driving behavior in favor of ecodriving is considered a crucial energy challenge. Results of that research shown that ecodriving support systems need to facilitate anticipatory driving and help users locate and maintain drivetrain states of maximum efficiency.

3. Legislation

Greening mobility is a global priority. The ‘‘White Paper’’, European Transport Policy for 2010: Time to Decide, was the first significant EU report that underlined the necessity to reduce transport generated CO_2 by reducing dependence on carbon based fuels (European Commission, 2001). Still many legislative documents and directives support the vision of green transportation, in order to provide guidance on and underline the necessity of greening mobility. Table 1, represents a list of indicative legislative documents.

Table 1. Legislative documents

The Kyoto protocol to the United Nations framework convention on climate change [COM(2007) 551; 2007]
Green paper. Towards a new culture for urban mobility; COM (2007) 551 [COM(2007) 551; 2007]
Communication COM (2007) 541 to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: towards Europe-wide safer, cleaner and efficient mobility: the first intelligent car report [COM(2007) 541; 2007]
Treaty of Lisbon amending the treaty on European Union and the treaty establishing the European Community, signed at Lisbon, 13 December 2007 [C306/1-271; 2007]
Communication COM(2008) 433 final to the European Parliament and the Council: greening transport
Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009. On the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC
Communication COM(2009) 490 final to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: action plan on urban mobility
Directive 2009/33/EC of the European Parliament and of the Council of 23 April 2009. On the promotion of clean and energy-efficient road transport vehicles
Regulation (EU) no. 443/2009 of the European Parliament and of the Council of 23 April 2009. Setting emission performance standards for new passenger cars as part of the Community’s integrated approach to reduce CO2 emissions from light-duty vehicles
Communication COM(2010) 186 final to the European Parliament, the Council, the European Economic and Social Committee: a European strategy on clean and energy efficient vehicles
Communication COM (2010) 2020 final from the Commission: Europe 2020—a strategy for smart, sustainable and inclusive growth
Regulation (EU) No 510/2011 of the European Parliament and of the Council of 11 May 2011. Setting emission performance standards for new light commercial vehicles as part of the Union’s integrated approach to reduce CO2 emissions from light-duty vehicles
Communication COM (2011) 112 final to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: a roadmap for moving to a competitive low carbon economy in 2050
Regulation (EU) No 510/2011 of the European Parliament and of the Council of 11 May 2011. Setting emission performance standards for new passenger cars as part of the Community’s integrated approach to reduce CO2 emissions from light-duty vehicles
Communication COM (2012) 582 final to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: a stronger European Industry for Growth and Economic Recovery
Communication COM (2013) 17 final to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: clean power for transport: a European alternative fuels strategy

4. Review of selected case studies

EVs are gaining ground worldwide with many applications and different approaches. Norway, for example, holds the largest per capita in the world fleet of plug-in electric vehicles, with over 100 plug-in EV passenger cars (March 2014) and with a total of 52,865 plug-in electric vehicles registered in the country in 2015 (49,296 are all-electric passenger and light-duty vehicles, and 3,569 plug-in hybrids). Norway has set a target to have a fleet-average CO_2 emissions from new passenger cars of 85 grams per kilometer (10 grams below the intended 2020 EU target of 95 grams) by 2020.

In Estonia, EVs have no tax and consumers prefer to switch from buying large cars to small and more efficient ones. Only fuel tax applies in the country, and it already reached the maximum EU level (around 6-% of the total retail fuel price). Moreover there is free charging of electric vehicle in Tallinn†.

† http://elmo.ee/elmo/

An urban scale approach worth mentioning is the Online Electric Vehicle (OLEV) buses operating in the city Gumi in South Korea. The wireless transfer of power to an electric vehicle when parked or in motion could extend driving range and enhance the convenience of recharging. A seven and a half mile stretch of inner-city road of Gumi, has been fitted with a wireless charging system to power an all-electric passenger bus. The OLEV system consists of electrical cables buried under the surface of the road that create magnetic fields which are picked up by a receiver on the underbody of the bus and converted into electricity. The length of the power strips installed under the road is generally 5 -15% of the road, requiring only a few sections of the road to be electrified. The bus receives 20 kHz and 100 kW electricity at an 85% maximum power transmission efficiency rate while maintaining a 17cm air gap between the underbody of the vehicle and the road surface. Safety to pedestrians is assured through compliance with international EMF (electromagnetic fields) standards. The road also has a smart switching function, with power only transmitted on the segments of roads on which the OLEV buses are travelling.

In terms of the HA:MO project, Toyota City in Japan, placed EVs (including cars, trains, buses, taxis, power-assisted bicycles and a network of over 100 shared ultracompact EVs intended for short journeys within the city) in the city center. Local scale example of EVs usage is the Schiphol airport in Amsterdam. EVs were considered as the best solution for its airside fleet. In the airport operate 8000 vehicles with typical journey along a fixed route under 4km. Therefore, the airport begun to electrify its fleet in 2013 with the installation of 35 all-electric buses. These buses are capable of running 250km on a single charge, proper for operating on such routes and there is considerable opportunity to right size the battery and further reduce the total cost of ownership.

In Bogota, Colombia, in 2013, the Municipality introduced an initiative to create the largest fleet of electric taxis in America, considering that taxis in Bogota were responsible for the majority of CO_2 emissions per passenger in the city‡.

Considering that 77% of drivers in Shanghai, China, drive daily less than 30km EVs were the best solution. Therefore, the municipality communicated the relative benefits of EVs aiming to raise awareness on EVs and keep drivers informed about the potentials of newer technologies. They conducted surveys to test drivers to establish their likes, dislikes, and purchase intents in an EV zone with a fleet of 160 electric vehicles from which usage data were collected and along with the data collected by the surveys, the municipality shared these data with vehicle manufacturers to help them establish a better understanding of the developing markets for EVs.

5. Greening Mobility Necessities

Although many attempts globally have been made to promote and install EVs it is important to develop and follow a comprehensive approach for greening mobility through promoting electromobility usage. Based on the above, we developed a “Greening Mobility Framework” to introduce the conceptual directives in order to meet and adopt future global energy challenges towards sustainability.

We do so, by considering among other facts, who is involved in the decision making process, how the mobility could be greener (considering different dimensions) and what are the expectations and the impacts of the proposed measures/actions for the transport system.

Based on the research of Clark-Sutton et.al. (2016), and the list of variables used in the city ranking of readiness to adopt EVs, we identified the Greening Mobility Necessities (GMN) that reflect to different environments and support the development of the proposed Greening Mobility Framework (GMF), represented in Table 2. The proposed GMF can be further modified to be adjusted upon specific needs and challenges and provide guidance in EU, National and local level of applications. In a National level, favorable taxes may apply for cleaner vehicles, electricity and infrastructures can support their usage while allowing selling electricity by other parties can also promote clean vehicles at a national level. From the local perspective; reserved and/or free parking spaces, emission zones and priority lanes for clean vehicle movements along with enabling opportunities for financial support for charging infrastructures are measures and actions required towards greening mobility. The GMF addresses the

‡ http://www.siemens.com/press/pool/de/events/2014/infrastructure-cities/2014-06-CCLA/bogota-climate-close-up.pdf

environment of intervention, the GMNs providing examples, while supports indicative recommended activities by presenting the main gains and motives.

Table 2. Greening Mobility Framework

Environment	GMN	Examples	Gains/Motives	Recommendations
Fuel cost environment	GAS price	Increase Gas price	Gain attractiveness for EVs	Develop the appropriate energy cost environment
	Electricity price	Reduce electricity price	Gain attractiveness for EVs	
	Adoptable PEV electricity cost depending on the time of use	Low electricity prices for overnight PEV charging	Gain money	
Purchase incentives	Purchase EV incentives	National or urban tax credits or rebate for consumers, business or governmental bodies to purchase a PEV	Increase competitiveness of PEVs in the car market shares	Purchase EV and EVSE incentives
	Purchase EVSE incentives	National or urban tax credits or rebate for business or governmental bodies to purchase a EVSE	Increase PEVs attractiveness and usage	
Fees	Reduced fees	Registration fees, vehicle tax, sale and use tax	Reduce PEV driver costs	Provide fee based motives to increase EVs attractiveness to the general public
Fleet programs	National/Urban fleet programs	Integrate PEVs into fleets, introduce electric vehicle car sharing services	Leading by example of demonstrating PEVs benefits, promote EV usage to citizens	Introduce special fleet programs
Infrastructure	Charging stations per capita	Appropriate number of charging stations in a city per capita	Reduce range anxiety	Provide adequate charging stations per capita properly located
Parking	Parking privileges	Free, reduced fee or reserved parking for PEV owners	Reduced parking costs and time	Provide parking privileges for EV usage
Traffic Management	HOV lane access	HOV lane access to PEV owners	Reduced travel time	Develop HOV lanes for EVs
	Emission zones	Most polluting vehicles are regulated in some way, either have no access or are charged	Create low emission zones Increase attractiveness for EVs	Create low emission zones and set strict emission levels
Human	Ecodriving	Educate/aware general public and promote ecodriving campaigns	Increase awareness, gain money, increase safety, reduce emissions	Educate/aware general public and promote ecodriving campaigns
	Feedback for surveys and observations	Develop surveys to address EV drivers and potential drivers' feedback, level of knowledge, awareness.	Collaborate with the general public in order to meet their needs	Observe drivers' mobility behaviour and get their feedback regarding their driving behaviour, needs and preferences, EVs usage assessment/ knowledge and awareness.

6. Conclusions

Remaining sustain by addressing future needs and support the global environmental friendly vision of transport and at the same time efficiently use new technologies consist the main aim of the proposed Greening Mobility Framework. What we can notice from the GMF, is that multiple actors and environments interact to accommodate and support the clean transportation vision of the future. A necessary precondition to make the GMF functional and effective is to increase awareness, understanding, and confidence in EVs amongst the general public. Addressing this requires active education and promotion efforts to create an informed public that is positively disposed to EVs.

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Designing a Vissim-Model for a Motorway Network with Systematic Calibration on the Basis of Travel Time Measurements

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Abstract

This paper describes a systematic calibration process of a motorway network in Vissim, based on travel time measurements that were derived from limited number of Bluetooth detectors. The case study that is developed, establishes an example for practitioners that are interested in designing motorway networks with microscopic simulation tools. The three-hour microscopic traffic simulation model that will be analyzed, replicates a motorway network which is located in the wider area of Bavaria in Germany and consists of 500 links, 113 nodes and 1820 origin-destination pairs. Model's systematic calibration and validation under the suggested approach show very good results in 96.5 % of the created intervals, for both cars and heavy vehicles.

Keywords: Vissim model; Systematic calibration; Motorway network; Simulation,

1. Background and Objectives

1.1. Systematic Calibration Processes

Over the last years, many systematic and comprehensive calibration processes have been developed in order to standardize the calibration process of traffic models. The aim of these systematic approaches has been to reduce the computational effort of the calibration process as well as to maximize the reliability of the exported results. However, these systematic procedures cannot produce reliable results in all situations. The main reason for this is the great variability of the traffic models and the different needs in every case that the practitioner has to cover.

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Modeling a signalized intersection in an urban environment consisting of multilane roads sets a higher level of complexity to the calibration process in comparison with a simple unsignalized intersection with three one-lane arms and low traffic volumes. In the first example a Vissim model is equipped with more operational details and more complex driving behaviors that require more detailed adjustment.

Except for the characteristics of the simulated model, another difficulty of developing a general systematic calibration process lies in the inability to set a rule to come up with the exact values of the parameters that must be adjusted in order to model precisely the driving behavior. Optimization algorithms are applied to reveal the optimum parameter set that will minimize the discrepancy between simulation results and field data. However, the number of the parameters that will be taken into consideration from the optimization algorithm, the range of parameters' values and the type of the parameters that influence the driving behavior still remain a nonstandard matter that cannot be restrained into general systematic procedures.

This paper's objective is to present and explain a manual systematic approach for motorway networks' calibration, based on automatic parameters' adjustment from similar traffic models and literature. However, the following approach can be applied to various traffic model cases.

1.2. Calibration based on travel time measurements

Travel times for motorway models are the most dominant and widely used way for calibration, mainly because they can be extracted from several detection ways such as Bluetooth (BT), Automatic Number Plate Recognition (ANPR), floating vehicle data etc. Except for the easiness of data extraction, travel time data enclose a great variety of information about the traffic situation especially under low or normal flow conditions. In this model travel times will be derived from BT detectors.

2. Traffic Model's Calibration Process

2.1. Calibration Process Overview

A microscopic traffic simulation model requires a variety of information as inputs. A model's level of fidelity is inextricably connected with those data. The higher the number of information a practitioner disposes, the higher the level of the model's accuracy will be. However, in many cases the collection of all the necessary pieces of information is rather difficult, either because the cost of the acquisition is becoming extremely high and will never be compensated or just because several aspects of the human driving behavior cannot be recorded easily or quantified. Hence, the practitioner is called to fine-tune the model by adjusting certain parameters until the exported data fall within an acceptable divergence from the real field data.

An uncalibrated model cannot replicate different traffic conditions with high accuracy. Calibration ensures that the developed model reproduces all the individual characteristics of a traffic situation, according to the targets that initially have been set. However, each microscopic simulation software package cannot contain all the aspects of driving behavior as fixed sets of parameters. For this reason, different parameters can be found in different traffic simulation tools. After several simulation runs, the analyst is responsible to come up with a certain set of parameters in order to achieve the desired proximity.

Calibration can be distinguished in two stages. The first stage concerns the reasonable adaptation of the input data in order to generate results as close as possible to the field data. The second stage is associated with the appliance of an optimization algorithm (Genetic Algorithm, Memetic Algorithm, Metaheuristic Algorithms, Simultaneous Perturbation Stochastic Approximation algorithm or others) (automatic adjustment), or with manual adjustment based on literature, practitioner's experience and/or similar models to determine the optimum parameter set.

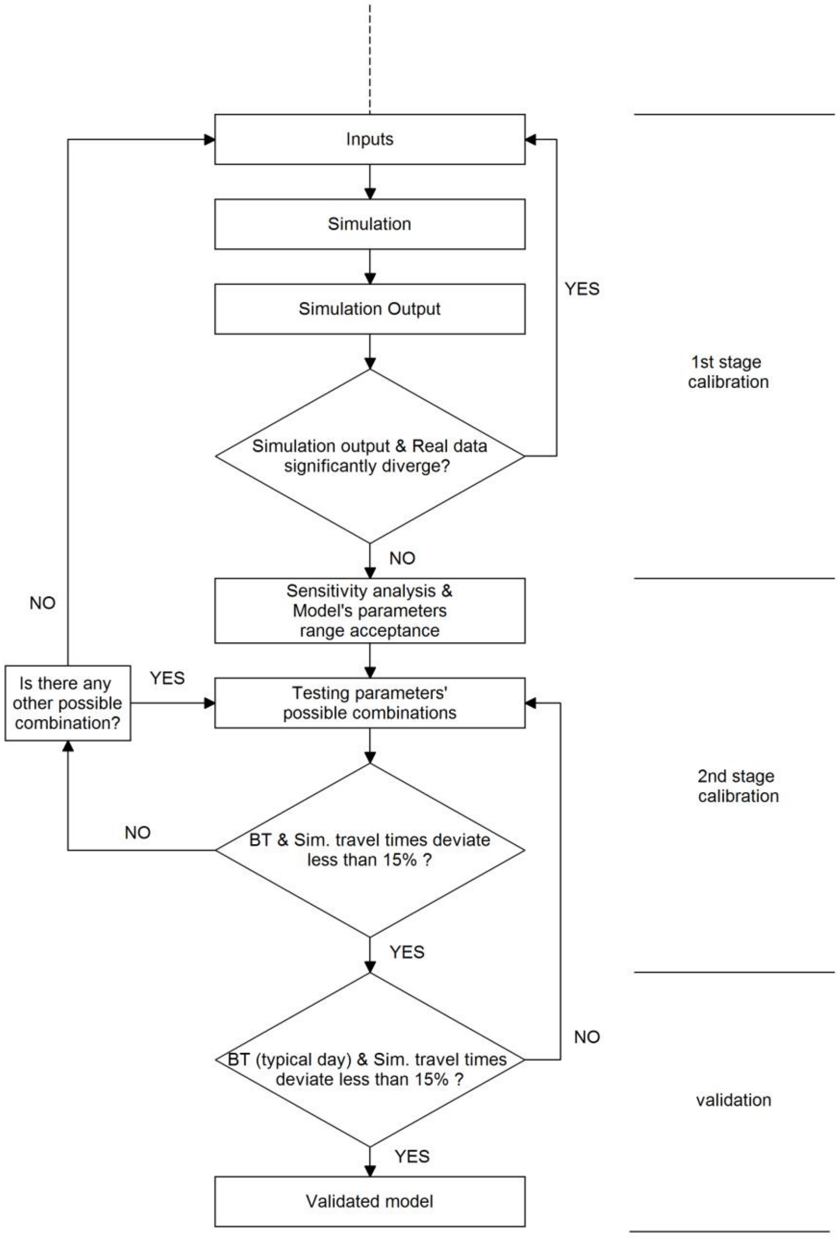

Fig. 1. Calibration process overview.

2.2. Calibration Targets

Calibration is a repetitive procedure until the desired correspondence between the field data and model's results will be eventually achieved. Nevertheless, perfect matching is nearly impossible, since the number of iterations in order to eliminate a re-occurring error cannot be infinite. Analyst's trials should be stopped when certain deviations are reached, according to the initial calibration thresholds that have been set. A prevalent example of calibration criteria is presented by the Wisconsin Department of Transportation (2002) for their Milwaukee freeway simulation model.

Table 1. Calibration Criteria, Wisconsin Department of Transportation (2002).

Criteria and Measures	**Calibration Acceptance Targets**
Hourly Flows, Model Versus Observed	
Individual link flows	
Within 15%, for 700 vph < flow < 2700 vph	> 85% of cases
Within 100 vph, for flow < 700 vph	> 85% of cases
Within 400 vph, for flow > 2700 vph	> 85% of cases
Sum of all link flows	Within 5% of sum of all links counts
GEH statistic < 5 for individual link flows	> 85% of cases
GEH statistic for sum of all link flows	GEH < 4 for sum of all link counts
Travel Times, Model Versus Observed	
Journey times network within 15% (or 1 min, if higher)	> 85% of cases
Visual Audits	
Individual link speeds:	
Visually acceptable speed-flow relationship	to analyst's satisfaction
Bottlenecks:	
Visually acceptable queuing	to analyst's satisfaction

The GEH statistic is an empirical formula computed as follows (Wisconsin Department of Transportation, 2002),

$$GEH = \sqrt{\frac{(V-E)}{\frac{(E+V)}{2}}} \tag{1}$$

where,

- V: counted volumes
- E: model's estimated volume

2.3. Typical Day

All data necessary for the simulation are collected on the day of our interest in accordance with the scope of the modeling. Usually, this day is a weekday that includes the peak hours to be simulated in our network (rare examples could be areas around, for example a zoo or a football field where the modeling interest shifts on weekends). However, second field data sets that can be used to calibrate and validate our network, are not always possible to be extracted the very same simulation day. In those cases, the new field data sets are derived from different days which are assumed to represent adequately the traffic behavior and characteristics of the simulation day. Nevertheless, due to traffic's variation and randomness the collected data may not represent a typical day. According to Wisconsin Department of Transportation (2002) the same GEH statistic formula adjusted, can guarantee at a satisfactory level the 'typical' character of the candidate day. The selection of a typical day can be implemented based on the comparison of the peak hour traffic volumes of a candidate day at any inductive loop with the average peak hour's volumes of all candidate days (Wisconsin Department of Transportation, 2002):

$$GEH = \sqrt{\frac{(Vi - Vaver)}{\frac{(Vi + Vaver)}{2}}} \tag{2}$$

where,

- Vi: volumes of candidate day
- Vaver: average volumes of all the candidate days

If in the 85 % of the selected detectors the GEH values are less than 5, then the candidate day can be selected as a typical day.

3. Building, Calibration & Validation – Motorway Network in Bavaria, Germany

3.1. Database

Satellite images were used to design and replicate in detail the layout of the study area. Traffic volume data were provided by Autobahndirektion Nordbayern for the peak hours 06:00 – 09:00 of a typical day. Travel speed and travel time data were given by Margreiter (2015). The heavy vehicle percentages were exported from a traffic survey by the Federal Highway Research Institute (2011) regarding all the motorways in Germany in 2010.

3.2. Data Processing

In order to insert the data in the microscopic simulation tool Vissim, first it is needed to process and organize them in compatible form to Vissim. The data were aggregated to the shortest possible intervals (30 minutes). The time intervals in general should be chosen depending on the size of the network, the duration of the simulation and the traffic flow on the motorway.

3.3. Model development

Great emphasis was given to the following coding steps:

- Warm up period: was considered as the time needed of the slowest vehicle to travel through the longest segment of the model.
- Route lane change on exit ramps connectors: is an important parameter and plays a major role on vehicles' lane selection. The route lane change distances were taken equal to 800 m - 1200 m if there were no other constraints (in real life situations, a vehicle driving on a motorway under normal traffic demand would switch to the correct lane(s) 150 m - 2000 m before the exit ramp, mostly depending on driver's road familiarity and road's space availability).
- Desired speed distributions: several speed categories were formed in order to reproduce the desired speeds coming from the processed data. The range of the speed values as well as the distribution in every category was decided based on the speed profile of every segment.
- Driving behavior: was set to 'Right-side rule (motorized)', since in German motorways overtaking on the inside is prohibited.

3.4. Calibration

Calibration based on travel times ought to be as detailed as possible. Therefore, average travel times for every vehicle type were exported from Vissim in order to measure the effectiveness of the calibration process. These average travel times for cars and heavy vehicles were compared with the respective real travel times from the BT detectors to see whether they deviate beyond the 15 % threshold or not. The calibration process was terminated once the travel times in all segments fall within the threshold. In order to normalize the results and to export reliable results in every calibration step, five simulation runs with different random seeds were performed (as proposed by PTV User manual (2014)). The whole calibration process relied on intervals where no incidents occured, since calibration at segments under incident depends highly on the unique characteristics of the incident (duration, severity) and the nature of the incident (accident, blockage of one/two/all lanes) and should be treated separately, according to the case.

First Stage Calibration Check

The criterion to determine whether the simulation output of a section within an interval significantly diverges or not, was the sign of the respective travel time deviations in all five simulation runs. More specifically, if the respective deviations in all simulation runs at one section present always the same sign (positive or negative), adjustments were made to the respective desired speed category (delegating a new neighbor speed category to that section). Otherwise desired speed category and distribution remained as they were.

For example, trucks' travel time deviations at the BT section 82-68 during 7:00 - 7:30 am were -2.8 %, -5.1 %, -3.5 %, -2.5 % and -4.1 % for the respective simulation runs. The aforementioned deviations mean that the trucks are moving faster than they should and therefore, their exported travel time measurements are lower than the respective BT travel time measurements. Trucks in this example had an average speed of 80 km/h which classifies them to the (80-85 km/h) 'Speed Category'. According to the adjustment that was made, the new assigned 'Speed Category' for them was the exact previous category of (75-80 km/h). It has to be highlighted here that a speed category at each section had been adjusted only once (if the deviations in the second calibration/validation process are higher than 15%, then a second round of adjustments could be performed) otherwise the travel speeds would become unrealistic.

Second Stage Calibration Check

The aim of the second calibration stage was to find the optimum parameter set, which would be used to fine-tune the Vissim model. Initially the parameters that were adjusted in order to replicate the simulated network's behavior were based on findings of a genetic algorithm which was developed for a 4820 m segment of the A9 motorway north of the city of Munich, Germany in the context of a master thesis by Xin (2013). Scope of this master thesis was to develop a genetic algorithm which would conclude to a set of parameters that provide reliable results for German motorways. The two models have a lot of similarities as both models' main focus was to simulate the traffic on on/off ramps, without occurrence of traffic incidents. Xin (2013) found out that the evaluation criteria were sensitive mainly to five parameters. Those parameters along with their selected values and their default values are depicted in Table 2.

Table 2. The five parameters that are mainly affecting models' results, according to Xin (2013).

Parameters	Xin parameters' selection	Default values
Headway time CC1 (s)	0.5	0.9
'Following' variation CC2 (m)	1	4
Max. deceleration trailing vehicle (m/s^2)	-3.8	-3
Safety distance reduction factor	0.5	0.6
Max. deceleration for cooperative braking (m/s^2)	-4	-3

After running the simulation five times, the majority (5 out of 92 travel time sections deviate beyond the 15 % threshold) of the travel time deviations fell within the 15 % threshold. However, the values for the car following behavior (CC1 and CC2) were considered unsuitable. Although, the combination of 0.5 seconds for CC1 and 1 meter for CC2 do belong to the typical ranges that are given in the literature, such a short 'Headway Time' along with a tight 'Following Variation' are not representing the driving behavior on German motorways under normal flow conditions. Therefore, new values for these parameters were investigated. Parameters for the lane change behavior kept the same, as Xin (2013) proposes, since no logical reasoning could be conducted and argumentation for anything different would be without solid justification.

Other papers by Gomes et al. (2004) and Rompis et al. (2014), which refer also to motorway model calibration, conclude to values for CC1 around 1.5, while concerning the CC2 parameter, Rompis et al. (2014) claim a value of

7.5. Although those highway networks are significantly larger than the one Xin (2013) examined and closer to the size of this network, they are more oriented towards calibration of highly congested motorway networks. Nevertheless, these parameters' values in combination with the previous lane change parameters were applied to this network, but the general performance of the simulation characterized overcautious and unnecessarily conservative, especially to segments with light traffic volumes between 6:00 am and 8:00 am (11 out of 92 travel time sections deviate beyond the 15 % threshold).

Judging from the two previous approaches which were considered too 'aggressive' and too 'defensive' respectively, it was obvious that a value that would replicate accurately the driving behavior comprehensively should be found in between the values of 0.5 to 1.5 sec for CC1 and 1 to 7.5 m for CC2. However, no further reference or logical justification could be provided to argue upon the selection of specific values between the upper ranges. Hence, to come up with the exact parameters' values, possible combinations within the two boundaries were considered. At this point, checking all the possible combinations would be a demanding, time-consuming process without real correspondence to the needs of this very calibration process. The combinations that were taken into account as shown in the following table provided very small deviations overall.

Table 3. Presumable combinations for parameters' CC1 and CC2 (fine tuning).

Presumable combinations	CC1 (s)	CC2 (m)
No 1	0.8	3
No 2	0.8	4
No 3	0.8	5
No 4	0.9	3
No 5	0.9	4
No 6	0.9	5
No 7	1	3
N0 8	1	4
No 9	1	5

Two simulation runs with different random seeds were performed for every possible combination. Best fit for the calibration was combination No 4 (CC1 = 0.9 sec, CC2 = 3 m) which was run three additional times and gave the final average deviation results (still 3 out of 92 travel time deviations were exceeding the 15 % threshold, see Table 4).

Table 4. Average absolute divergence percentages of travel times in 30 min intervals.

Absolute average divergence percentage from Real travel times														
Segment	BT Position		Percent %											
			6:00 - 6:30		6:30 - 7:00		7:00 - 7:30		7:30 - 8:00		8:00 - 8:30		8:30 - 9:00	
			5400 - 7200		7200 - 9000		9000 - 10800		10800 - 12600		12600 - 14400		14400 - 16200	
	From	To	Cars	HV	Cars	HV	Cars	HV	Cars	HV	Cars	HV	Cars	HV
A70	-	-	-	-	-	-	-	-	-	-	-	-	-	-
A7	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	93	94	1,5	6,0	1,6	7,6	1,9	2,3	2,9	5,8	0,8	6,9	5,4	2,5
	94	85	3,4	3,9	4,0	3,9	5,7	3,6	1,0	2,8	4,7	5,0	8,1	5,3
A6	83	82	4,0	5,6	8,1	7,4	6,4	1,2	10,4	2,7	13,6	1,6	14,2	0,8
	82	68	5,4	3,7	11,3	1,5	5,0	2,8	10,7	2,4	11,6	5,2	14,2	3,2
	68	86	12,5	4,3	6,2	1,7	8,1	2,7	9,8	3,9	14,7	6,3	14,5	5,5
A73	86	87	-	-	-	-	-	-	-	-	-	-	-	-
A9	87	47	-	-	-	-	-	-	-	-	-	-	-	-
	47	81	1,3	1,1	2,0	1,1	7,3	2,2	8,0	1,3	3,1	1,9	0,7	0,9

A3	78	89	-	-	-	-	-	-	-	-	-	-	-	-
A73b	-	-	-	-	-	-	-	-	-	-	-	-	-	-
A3b	92	91	2,7	3,0	4,0	4,9	2,7	3,3	6,9	4,4	-	-	-	-
	91	90	6,4	1,4	8,8	3,2	5,9	1,3	16,7	1,0	23,3	1,7	28,4	3,3
	90	89	-	-	-	-	-	-	-	-	-	-	-	-
														**No data or incident: -*

However, a closer look on results from all three calibration approaches indicated that cars' travel time deviations in section between BT 91-90 at A3b segment during 7:30 am - 9:00 am are repetitively not complying with the targets that have been set. This can be attributed to the incompatibility of the data sets to this segment (speed related data and traffic volumes came from different - but typical - days) or insufficient calibration.

3.5. Validation

Having all errors wiped out and simulation parameters determined, the calibrated travel times will be compared to a fresh travel time data from another day. A properly calibrated model ought to produce travel times within the thresholds that have been set, otherwise it needs further calibration. Validation process is the one that ultimately verifies that a model outputs reliable data which can be used for various purposes. However, before examining if the travel time deviations lie within the thresholds, the typicality of the new travel time dataset should be checked.

4. Conclusions

This paper proposed a systematic manual calibration process for a motorway network model. The calibration was achieved in two stages. The first stage referred to a reasonable adjustment of the input data (desired speeds) in order to minimize the divergence from the field data (Bluetooth travel times), while the second stage referred to the selection of the optimal parameter set. In order to conclude to the optimal parameter set, a certain zone of suitable parameters' values was determined based on Xin (2013) and Rompis et al. (2014). The optimum values were selected based on a repetitive process of trial and error in the delimited zone.

Assessing the efficiency of the calibration approach, we can safely conclude that 96.5 % (89 out of 92) of the formed intervals are complying with the calibration targets. More precisely, heavy vehicles' highest divergence from the real data is 7,6 % (< 15 %) while 93.5% of cars travel time deviations' fall within the determined thresholds (43 out of 46).

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Assessing the performance of intermodal city logistics terminals in Thessaloniki

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Abstract

The purpose of this paper is to present a comparative analysis of two urban intermodal freight transport terminals focusing on last mile distribution; the port of Thessaloniki (ThPA) and Kuehne + Nagel (K+N) distribution center. The paper enables the pairwise comparison of different intermodal freight transport nodes acting as interchanges in a supply chain with a special focus on the last mile distribution. The final outcome of the analysis is the creation of an auxiliary or subsidiary tool addressed to potential decision makers (e.g. shippers, forwarders, transport companies, users or customers of the two terminals within the supply chain). The evaluation of the terminals' performance is elaborated based on a tailored multi criteria key performance indicator KPI-based assessment framework, while the selection and significance (weight) of the incorporated criteria and KPI's is predetermined by the involved stakeholders imposing their point of view through an analytical hierarchy method. ThPA terminal was ranked first according to its performance pertaining to the role of an intermodal interchange, however K+N terminal's performance index was slightly lower, while in several KPIs and criteria it seemed to perform better.

Keywords: city logistics, multi-stakeholder, multi-criteria evaluation framework, key performance indicators, comparative analysis, performance indices, sensitivity analysis, AHP, PROMETHEE, GAIA

1. Introduction

Taniguchi et al. (1999) define city logistics as "the process for totally optimizing the logistics and transport activities by private companies in urban areas while considering the traffic environment, the traffic congestion and energy consumption within the framework of a market economy" (Taniguchi et al., 1999).

The first organized freight activities and related facilities focusing on city logistics were established in the context of urban areas in the 1960's. Due to urbanization trends prevailing during that time, the first freight and logistics terminals were set up as consolidation and distribution points inside the urban web in order to satisfy the continuously growing demand generated nearby. These patterns of increasing activity have been shaped since late 1970's and created significant demand for goods. During the next two or three decades, given the urban sprawl and the creation of metropolitan areas with increased congestion and spatial problems emerging, many of those facilities were established near or just outside cities. In the 2000's, the modernization of city distribution techniques, namely the on-line delivery, created the need for individual and personalized trips in the context of last mile delivery service, increasing the traffic and environmental burden. Lately, the economic recession and the continuously growing city's

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web attracting all business activities have reversed the decentralization efforts made from the side of the government and the local authorities favoring urbanism once again. Urban areas have been plagued by the impacts of the ongoing economic crisis to a great extent and this has resulted in changes in the urbanization trends.

Transport demand resilience for a given population and supply system depends on the level of provided services, which is correlated with the innovative, smart and integrated ICT and city logistics solutions used for freight assignment or during the diffusion of related data and information (BESTUFS, 2015). The twenty-first century will be a century of urbanization, since growing cities attract people due to the fact that more educational and leisure activities take place and there are more opportunities in creating new jobs. To this end, the problem of the supply of goods within urban context gained importance and, in turn, city logistics have proven to be a great challenge. That is why the European Commission's interest is focused on the promotion and funding of sustainable urban mobility plans (SUMPs) incorporating all freight activities which coexist and co-act with passenger transport within the same transportation network, resulting mainly in traffic problems and environmental impact deteriorating the citizens' quality of life.

Cities face adverse impacts and so countermeasures have been introduced in order to improve the urban working and living environment. Noise nuisance, land use restrictions, increased freight trips and respective environmental impacts have caused the shifting of logistics facilities and the mitigation of their activities to exurban areas (Diziain et al., 2012). The issue of urban sprawl for economic activities and especially logistics is not new; historically, the location of logistics terminals was close to adjacent rail networks. Today, those terminals tend also to locate as close as possible to highway networks, airport areas (Rodrigue, 2004; Woudsma et al., 2007), and especially ports, the role of which is not restricted anymore only to the transshipment point for freight, but is extended to various roles within the supply chain (Mangan et al., 2008).

The performance of freight terminals relies on the performance of multiple processes that are undertaken within these areas. The role and performance of interurban freight terminals affect the performance of urban distribution to a great extent, most often determining the city logistics' system structure. Regarding freight terminals that are located in the suburban and interurban areas, they play a critical role in the goods' distribution to the nearby cities as well. The freight assignments are organized in freight terminals in order for the goods to be forwarded to regional destinations more efficiently. In consolidation centres, different shippers and transport and logistics service providers co-operate and intermodal terminals exploit the benefits of long distance transportation (e.g. maritime, rail) and last mile delivery (trucks), in a seamless way. Higher load factor of trucks, less traffic congestion and less environmental emissions are achieved (De Souza et al, 2014).

The aim of this paper is to develop and demonstrate the assessment of the performance of two intermodal freight and logistics terminals, using a multi-criteria approach which takes into account most parameters concerning the wider supply chain and facilitates the decision-making process in the optimum terminal selection. The methodology is implemented in two terminals in Greece, a privately operated rail-road freight terminal, and the Port of Thessaloniki. A short profile of the two freight terminals is given below:

1) The private terminal is an inland intermodal freight terminal, managed and operated by a logistics service provider and forwarding company (Kuehne+Nagel), which imports and exports goods to/from Greece also including last mile distribution in greater Thessaloniki area using the road and railway network.
2) The port of Thessaloniki is managed by Thessaloniki Port Authority S.A. The port provides handling services for various types of cargo, shipping services, passenger maritime services and customs services. Apart from the trucks, accessibility to the freight terminal is provided by rail underpinning intermodality.

This paper reviews and implements methodologies, transport and logistics related network models and Key Performance Indicator (KPI) - based methods for the comparison of the two terminals, in terms of size, handling equipment, hours of operation, throughput (e.g. containers' arrivals) and other components. In addition, it examines the ownership and operational characteristics of the terminals and highlights the efficiencies and the reasons for customer and freight forwarder choice of a particular terminal, which is of great interest to the overall supply chain considerations in the context of decision making from the side of the terminal users. For the evaluation, a Multi-Criteria Assessment (MCA) method, based on Analytic Hierarchy Process (AHP), is used. The expected outcomes include a comparison of the performance of these terminals indicating the most effective one with respect to the performance criteria that are set and a case-specific discussion about the most efficient type of intermodality in order to support the last-mile distribution. The evaluation framework is based on criteria and their KPIs. Both criteria and respective KPIs, as well as their significance (weight) in the evaluation process are selected by the stakeholders involved in the operation of the two terminals, within the context of a Multi Stakeholder Multi Criteria Assessment Framework. Pairwise comparison has been used to assess the two terminals' performance against the selected criteria and indicators.

Presentation of the above is done in the succeeding five sections, which incorporate the following:

- Development of the methodological framework, concerning the terminals' analysis and pairwise comparison. In this section the description of the structuring of the AHP utilized for the identification of the criteria, selection of the KPIs and allocation of weights to criteria and KPIs is also provided.
- Presentation of the numerical values concerning the terminals based on the quantification of KPIs. The two terminals' pairwise comparison results based on their performance indices are also depicted.
- Elaboration of a sensitivity analysis in order for the validation of initial results to be conducted.
- Visualization of the two terminals' prioritization results through proper software.
- Elaboration of important conclusions for decision making.

2. Methodological framework

Pertaining to the pairwise comparison of the two terminals concerning their efficiency and attributes, but also in light of their impacts on the urban distribution, the methodological framework adopted was shaped as follows:

1. **Definition of criteria and performance indicators**
   The criteria which were used regarding the assessment of the performance of these terminals are: management policy, supply side performance, organizational and institutional structure, terminal properties and level of service (Järvi and Nagel, 2013).
2. **Weight allocation to criteria and indicators**
   This was done by a pairwise comparison, and finally they resulted in eigenvalues, which comprise the weights assigned to each criterion and KPI.
3. **Quantification of the performance indicators**
   Each performance indicator was quantified, based on data collected by the managing companies and provided to the authors for this analysis.
4. **Prioritization of the terminals**
   The collected data was combined and the prioritization of the terminals was resulted, based on the integrated and individual evaluation scores.

The assessment of the two terminals was elaborated through a "multi criteria evaluation framework" based on criteria and their KPIs selected through the Delphi Method (Criteria Assess and Measure Evaluation process) by a panel of experts constituted of the terminals' representatives and the authors, also considering the availability of respective data. Towards a more holistic approach, both quantitative and qualitative criteria and indicators are incorporated in the analysis. In particular, based on the analysis of intermodal interchanges elaborated within the European Research project CLOSER (EU FP7) (Christiansen et al, 2012), several KPIs were selected and grouped under five criteria. Some additional indicators were also incorporated based on the authors' previous experience on terminal performance assessment from the project STRAIGHTSOL (EU FP7) (Andersen et al, 2014) and the INTERREG III B CADSES project IMONODE (Nathanail et al, 2005; Nathanail, 2007). The numerical values of the KPIs were either accumulated as raw data through the terminals' annual reports or estimated based on information acquired by the terminals' representatives in the context of individual interviews.

After the quantification of each KPI, their respective grades were determined based on the grading scale used in the aforementioned projects, always in communication with the terminals' representatives, adjusting the final grading scale taking into account their personal experience and expertise in this field adopting the DELPHI method. In addition, the significance of each criterion and respective KPI was investigated through the elaboration of a pairwise comparison in the context of the Analytic Hierarchy Process (AHP), in order to come up with their individual weights applied in the multi criteria analysis. All the stakeholders involved in freight assignments elaborated through those terminals participated in the establishment of weights through the AHP. Their viewpoints were recorded through a questionnaire survey organized and implemented by the authors of this paper during the last half of 2014, in order to gain a holistic multi stakeholder multi criteria approach. The AHP was selected as it is one of the Fuzzy Multiple Criteria Decision Making methods, providing not only a simple and very flexible model for a given problem, but also an easy applicable decision making methodology that assist the decision maker to precisely decide the judgments (Saaty, 1977; Chen and Wang, 2010; Li and Li, 2009; Nathanail et al., 2014).

Based on the prioritization and weighting of criteria and respective KPIs, the pairwise comparison of the two terminals is elaborated to indicate which of the two is more efficient regarding its services and performance, in order to provide a valid decision making tool for terminal selection. The prioritization of the two terminals is then tested through a sensitivity analysis which constitutes a technique used to determine how different values of an independent variable will affect a particular dependent variable under a given set of assumptions. Finally, the illustration and validation of the results is provided by PROMETHEE and GAIA software.

3. Terminal comparative analysis

The implementation of the methodology on the two terminals, leads to results which constitute a handy decision making auxiliary tool for freight assignment employing maritime and road transport modes or rail and road transport modes using the supply chain destined to Thessaloniki city for last mile delivery. The multi criteria assessment framework is based on five criteria: Management policy, Organizational and institutional structure, Supply side performance, Terminal properties and Level of service (Nathanail et al, 2016).

The terminal comparative analysis is accomplished through the elaboration of a multi stakeholder multi criteria assessment framework. This framework was based on the values of those criteria and respective indicators, also taking into account their weights as determined by the involved stakeholders through the AHP. The grades of the KPIs were produced based on their numerical value and the grading scale determined based on literature review (Nathanail et al, 2005; Nathanail, 2007), also taking into account the involved stakeholders' point of view on that through the Delphi method. In particular, based on the review of available sources and the expert group's opinion, the grading scales were determined through a range of numerical values decided by the expert group after brainstorming, taking into consideration all the special characteristics and conditions in the area of study. The partial and total performance indices of the two terminals (Port of Thessaloniki and Kuehne+Nagel) are presented within Table 1.

Table 1. Partial and total performance indices of Port of Thessaloniki (ThPA) and Kuehne + Nagel (K+N) terminals (Nathanail et al, 2016)

	Performance index	
Criterion	**Thessaloniki Port Authority**	**Kuehne+Nagel**
Management policy	2.6	5.6
Organisational and institutional structure	8.5	7.9
Supply side performance	7	4
Terminal properties	7.1	6.45
Level of service	7.9	7.2
All criteria (Total Performance Index - TPI)	**6.815**	**6.2375**

It was observed that Kuehne+Nagel's terminal performs better concerning the first criterion on "Management policy" due to the high multimodality rate and the higher performance on environmental burden, as well as safety and security issues. On the other hand, the Port of Thessaloniki terminal prevails when it comes to all the other criteria due to higher productivity of both personnel and equipment, while also being a little better performing in "terminal properties" and the provided "level of service" to partners and customers. Overall, the Port of Thessaloniki terminal outmatches Kuehne+Nagel's terminal by 6.815 to 6.2375.

In order to further validate the results, a sensitivity analysis was elaborated as well. Through the increase or decrease of each criterion's weight by 10%, an effort is made to investigate any modification in the prioritization of the terminals concerning their partial and total performance indices. In particular, each time the emphasis (+10%) or the demotion (-10%) is set on one criterion, according to the common methodology adopted in similar cases based on the literature review (Nathanail, 2007). Thus, each criterion's weight is firstly increased and then decreased (one at a time) counterbalancing accordingly the rest of the criteria weights (respectively increased or diminished in order for all criteria weights to sum up to 100%). The respective performance indices are depicted within Table 2.

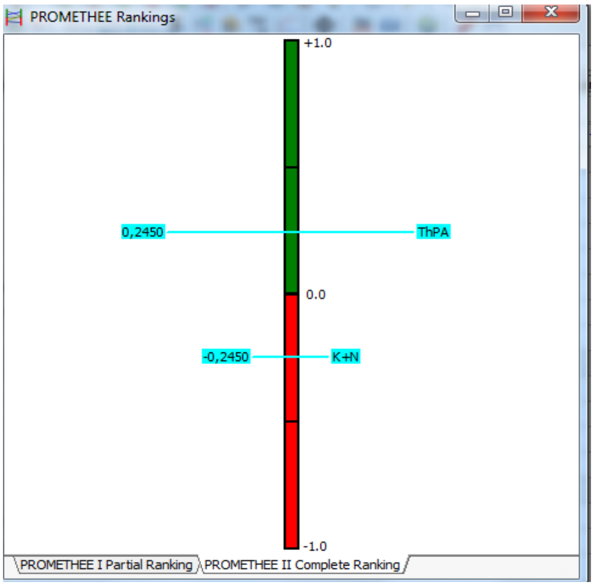
Table 2. Partial and total performance indices increasing / decreasing criteria weights (Nathanail et al, 2016)

Criterion	**Total Performance Index (TPI)**	
	ThPA	**K+N**
Management policy (+10%)	6,3125	6,15875
Management policy (-10%)	7,3175	6,31625
Organisational and institutional structure (+10%)	7,05	6,44625
Organisational and institutional structure (-10%)	6,58	6,02875
Supply side performance (+10%)	6,8625	5,95875
Supply side performance (-10%)	6,7675	6,51625
Terminal properties (+10%)	6,875	6,265
Terminal properties (-10%)	6,755	6,21
Level of service (+10%)	6,975	6,35875
Level of service (-10%)	6,655	6,11625

The modification of each of the criteria weights by 10% does not have any impact in the prioritization of the terminals, as the ThPA's terminal still has a higher total performance index compared to K+N's terminal in all of the cases. This outcome proves the stability of the prioritization results for a weight fluctuation of ±10%.

4. Visualization of results

With view to provide an auxiliary decision making tool, also setting the visual effect on scene, in order for the final results on terminal prioritization to be more integrated and representative, the preference ranking organization method for enrichment of evaluations (PROMETHEE) and GAIA method ware used. The prioritization of the port of Thessaloniki (ThPA) terminal over Kuehne + Nagel (K+N)'s terminal is further justified through those two terminals' attributes, facts and figures comparison in PROMETHEE. In particular, within Figure 1 (a), the supremacy of ThPA over K+N is depicted through PROMETHEE I (partial ranking) of their respective "preference flows" (phi+ and phi-), but also through PROMETHEE II (complete ranking) in Figure 1 (b).



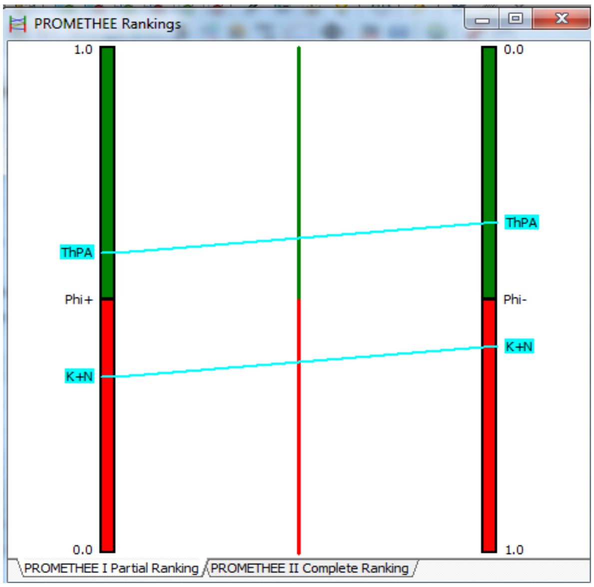


Figure 1: Prioritization of terminals: a) Partial ranking, b) Complete ranking

The preference flows are computed to consolidate the results of the pairwise comparisons of the terminals and to rank them from the best to the worst. The positive preference flow Phi+ measures how much ThPA is preferred to K+N. It is a global measurement of the strengths of the terminals. The larger Phi+ the better the terminal is. On the other hand, the negative preference flow Phi- measures how much the other terminal (K+N) is preferred to ThPA. It is a global measurement of the weaknesses of the terminals; the smaller Phi- the better the action. As the two preference flows are consolidating the pairwise comparisons of the actions according to opposite points of view, they usually induce two different rankings on the set of actions. The partial ranking is the intersection of these two rankings. So, ThPA terminal is preferred to K+N terminal if and only if the inequations (1) and (2) are valid (which is the situation in our case).

$$\text{Phi+ (ThPA)} \geq \text{Phi+ (K+N)} \tag{1}$$

$$\text{Phi- (ThPA)} \leq \text{Phi- (K+N)} \tag{2}$$

The PROMETHEE II ranking is a complete ranking. This means that both terminals are compared and that the ranking includes no incomparabilities even when comparison is difficult. The resulting ranking can thus be more disputable, especially in the presence of strongly conflicting criteria. The ranking is based on the net preference flow-Phi, which is the balance between the positive (Phi+) and negative (Phi-) preference flows. It combines the two other preference flows in a single summary score. So ThPA is preferred to K+N in the PROMETHEE II ranking if and only if ThPA is preferred to K+N according to the net preference flow (which is the situation on our occasion).

The PROMETHEE diamond, presented in Figure 2 (a) constitutes an alternate view of the PROMETHEE rankings. Practically, it is an alternative two-dimensional joint representation of both PROMETHEE I and II rankings. The square corresponds to the (Phi+,Phi-) plane where each action is represented by a point. The plane is angled 45° so that the vertical dimension gives the Phi net flow (summary of Phi+ and Phi- per terminal). Phi+ scores increase from the left to the top corner and Phi- scores increase from the left to the bottom corner. For each action, a cone is drawn from the action position in the plane. As ThPA cone overlaps K+N's cone, it is the preferable one in the PROMETHEE I partial ranking. An advantage of the PROMETHEE diamond is that it is easy to visualize the proximity between Phi+ and Phi- scores globally. In our situation, there is no incomparability and the dominance of ThPA over K+N is clear as both coefficients (Phi+ and Phi-) of the first are bigger than the respective ones of the second.

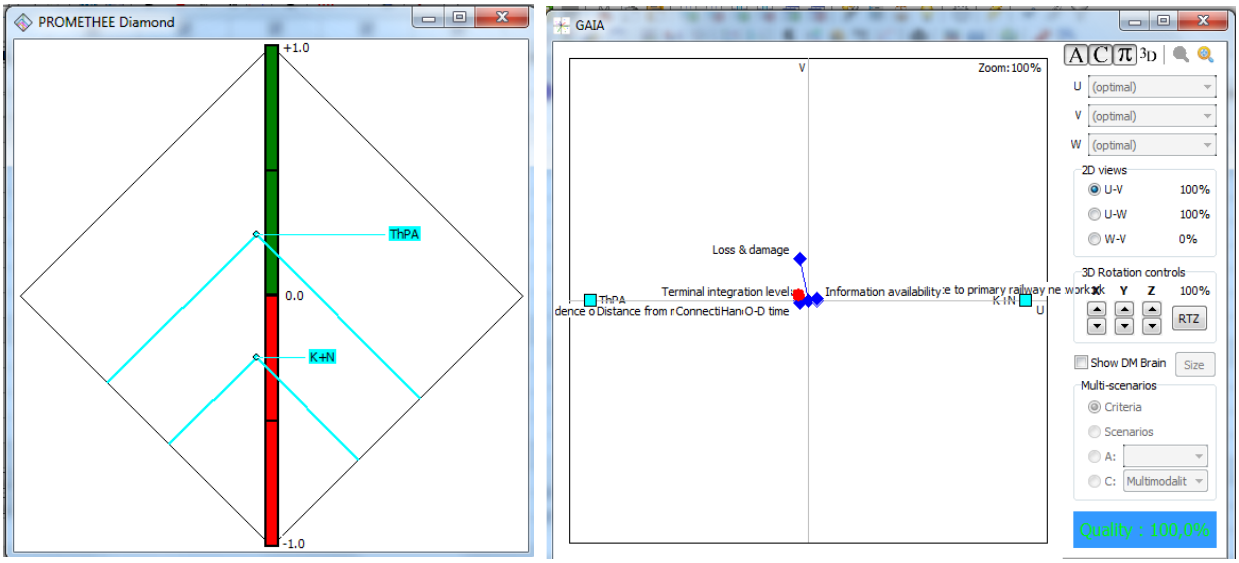


Figure 2. Ranking of terminals: a) PROMETHEE diamond, b) GAIA visual analysis

Finally, in Figure 2 (b), GAIA uses a dimension-reduction technique that is borrowed from statistical data analysis. This technique is called the principal components analysis (PCA). PCA allows the definition of a series of orthogonal dimensions (principal components) that keep as much information as possible on the relative positions of the actions in the k-dimensional space. Due to the large number of KPIs, it is difficult to clearly discriminate all KPIs. However, it is recorded that the vertex of each KPI is destined to the prevailing terminal (ThPA or K+N): i.e. almost all of the KPIs of the "Management policy" criterion are in favour of K+N's terminal, while the majority of the KPIs of the other four criteria are closer to the ThPA's terminal.

5. Conclusions

In the framework of this paper, two terminals, potentially involved in Thessaloniki's supply chain and last mile (urban) distribution, were prioritized through a pairwise comparison, being evaluated as per their attributes and general performance (facts and figures) according to a Key Performance Indicator (KPI)-based multi stakeholder multi criteria assessment framework. In order to estimate the significance of each criterion and KPI in the analysis, all involved stakeholders imposed their point of view through the elaboration of Analytic Hierarchy Process (AHP).

Based on the results and findings, the port of Thessaloniki (ThPA) terminal is ranked first according to its performance pertaining to the role of an intermodal interchange. The ThPA's terminal predominance over the one of K+N is further validated through the elaboration of sensitivity analysis in the context of which the weights of criteria are increased and diminished accordingly by 10% in order to avoid objectivity. The results are further supported and visualized through the PROMETHEE and GAIA methods used for integration and representation through graphs.

Nevertheless, Kuehne + Nagel (K+N) terminal's performance index is only 8,5% lower than ThPA's, while in several KPIs and criteria it seems to perform better. The prevailing ranking of ThPA versus K+N is validated through a sensitivity analysis, while the final result is also justified through the PROMETHEE method, with use of the respective software. Although simpler processes could have been used to derive the same conclusions, the Multi-Stakeholder Multi-Criteria evaluation was selected as the most objective, integrated and holistic approach.

The final outcome of the analysis is the creation of an auxiliary or subsidiary tool to potential decision makers (e.g. shippers, forwarders, transport companies etc. users or customers of the two terminals within the supply chain). To take this one step further, with appropriate adjustments, to provide the potential decision maker with solid answers and solutions as well as with a useful tool, this paper enables the pairwise comparison of different intermodal freight transport nodes acting as interchanges in a supply chain with a special focus on the last mile distribution. So, it may well be used in order to support future decisions in the context of strategic planning concerning scenarios associated with the establishment of different kind of facilities in a given area, where the justification of the decision will have to take into account different criteria, trends, trade-offs and of course huge private and public investments and collaboration or business schemes, directly affecting the quality of life and the economy of the local area or of a broader geographical region or socioeconomic territory.

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Review of intelligent transport solutions in Latvia

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Abstract

The goal of the following paper is to make a review of existing intelligent transport solutions in Latvia. The results of the review were part of the RITS-NET project, implemented in frame of INTERREG IVC programme by consortium of partners from 9 EU countries, including Latvia. The project aims at enhancing regional sustainable transport policies via an increased knowledge and understanding of the full potential of Intelligent Transport Systems (ITS) solutions and ways to deploy them. To reach the goal the state-of-the-art of intelligent transport solutions in Latvia was completed, taking into account following subtopics: Emergency Management and Incident Services; ITS for Traffic Management and Mobility; Parking and Automatic Payment; ITS for Public Transport Management; Fleet Management and Freight. On each subtopic the careful review of existing solutions were completed and described.

Keywords: intelligent transport solutions, state of the art, sustainable transport network, Latvia

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1. Introduction

Modern information and communication technologies plays significant role in establishment of the sustainable transport network, usually the definition of the sustainable transport network includes direct reference to the potential users of the transport, as example “satisfying current transportation and mobility needs without

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compromising the ability of future generations to meet these needs" (Black, 1996) or the definition from Centre for Sustainable Transportation (Cst.uwinnipeg.ca, 2016) "sustainable transport system as one that:

- allows the basic needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, with equity within and between generations;
- is affordable, operates efficiently, offers choice of transport mode, and supports a vibrant economy
- limits emissions and waste within the planet's ability to absorb them, minimizes consumption of non-renewable resources, reuses and recycles its components, and minimizes the use of land and production of noise".

The definitions mentioned above point on wide range of factors, which must be taken into account developing sustainable transport network, but in the center is a person, who is a user of the transport network. As one of the effective tools the use of information communication ICT could be declared. By using ICT the transport network become "intelligent" and more "friendly" to the end users. But implementation of ITS is an issue of different factors: financial abilities of the city/region/country, readiness of the end users to accept new solutions etc.

The paper goal is to make the review of the intelligent transport solutions in Latvia. In order to make review more detailed and structured the following declaration of ITS subareas was used: Emergency Management and Incident Services; ITS for Traffic Management and Mobility; Parking and Automatic Payment; ITS for Public Transport Management; Fleet Management and Freight. The definition of the areas was done based on experience from RITS-NET project (RITS-NET, 2016) and POLITE project (Yatskiv et al., 2013) both completed in frame of INTERREG IVC programme.

2. State-of-the-art of intelligent transport solutions in Latvia

Following section describes the review of the ITS solutions use in Latvia for different fields of activities: Emergency Management and Incident Services; ITS for Traffic Management and Mobility; Parking and Automatic Payment; ITS for Public Transport Management; Fleet Management and Freight.

2.1. Emergency Management and Incident Services

Emergency management and incident services are not well developed in Latvia from point of ITS. Two national emergency service institutions are responsible for managing an emergency and incidents: State Fire and Rescue Service and Emergency Medical Service. The structural units of both are located across all Latvia.

Latvia supports single emergency telephone line - 112. The single emergency telephone line is operating since 1997. From organization point of view: Central call station is located in Riga, additionally 4 regional call stations are operating. Single emergency telephone service receives around 5000 calls per day.

On 2011 the Minister of Transport signed the Memorandum of Understanding for Realisation of Interoperable In-Vehicle eCall (Eena.org, 2011). In 2016 one of the biggest mobile operators of Latvia Tele2 announced that is has prepared its communication network for the introduction of the eCall system (Telecompaper.com, 2016).
According to the plans following important dates could be noted (Eu2015.lv, 2016):

- From 31 March 2018, car manufacturers will have to equip all new models with an in-vehicle technology that will communicate with the 112-based eCall interoperable service
- The infrastructure for the eCall system should be in place by 1 October 2017. Its use will be accessible to all consumers and free of charge.

2.2. ITS for Traffic Management and Mobility

Traffic and Travel Information is a key element of ITS deployment. As the part of EU Latvia shall follow and harmonize national policy with EU directives. In 2010 EU has publish directive 2010/40/EU (EU, 2016), the directive refers to the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport. ITS in Latvia is still under development and most important that there is no one strategy how ITS system should be developed and implemented. But following services and ITS solutions in frame of Traffic and Travel Information area related could be mentioned here as examples:

Traffic Information

Traffic information and control centres for national road network and some big urban municipalities (Riga, Jelgava), as public services, were introduced in the last five years, having primary orientation on common needs of road users. For instance, traffic information centre of national road network receives notifications on critical traffic situations from different official bodies and road users, as well as has a direct input from the field devices. Traffic centres maintain all the accessible data, sharing traffic information to media, road users and among responsible authorities in different ways. Currently existing system could be presented in Fig. 1.

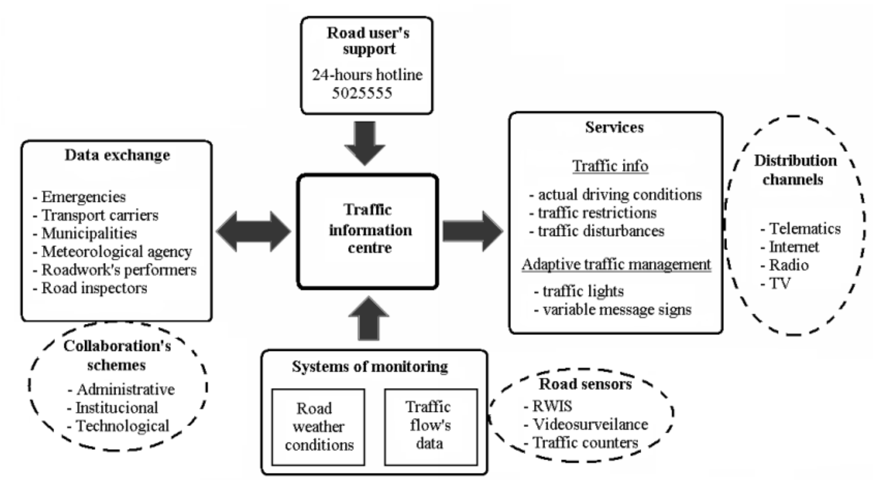

Fig. 1. Functional architecture of ITS in Latvia (Jeļisejevs, 2010).

The traffic information is provided and managed by SJSC "Latvian State Roads". The company manages up to 188 data collection points across Latvia. The on-line and historic data about traffic intensity are available for public on webpage http://www.lvceli.lv/traffic/.

Traffic restrictions

Another service provided by SJSC "Latvian State Roads" is information about restriction areas in transport network (with additional commenting information). The information about restrictions is available on webpage http://lvceli.lv/lat/celu_lietotajiem/satiksmes_ierobezojumi/.

Road weather information system

In the same time SJSC "Latvian State Roads" manages RWIS (Road Weather Information System). The system is presented by 53 stations (some of them are combined with traffic intensity measurement points) and central system for data processing. RWIS software is in house-developed by road administration and data collection point technical maintenance is outsourced. The collected data are available for "Latvian State Roads" staff (limited access) and for public access.

- The limited access data consist of traffic profiles, video surveillance and specific meteorological data (forecasts, alarms, radar and satellite images, numerical models etc.) This information is needed for road maintenance.
- The data provided for public use are published on international portal on road weather conditions (real-time data, mostly descriptive for driving conditions) in Baltic countries. The data are available on www.balticroads.net. The webpage is available in 6 languages (Estonian, English, Russian, Lithuanian, Latvian, and Finish).

The system provides number of different characteristics for data collection points, like air temperature, road temperature, air humidity, dew point, wind speed and so on. In the same time pictures from cameras are available.

Travel Information

As was mentioned in first paragraph Latvia tries to create unified ITS. This also concerns travel information systems. There two widely used services which could be used in all Latvian territory to manage public transport journeys. These services are presented in form of webpages and are available for public usage.

1188 – Information service

This service provides opportunity to plan the trip by public transport (intercity buses, trains, ferries). In order to use the service, the origin station and destination station must be selected. The search will return information about all possible routes (in frame of one transport mode). The users have ability to see information about trip duration, price, distance, number of stops and route by itself (visualized on the map).

Bezrindas.lv – service

The second service is a webpage mainly orientated on tickets selling. The functionality of the service and disadvantages are the same as for the previous one. Additionally the user has opportunity to buy tickets on-line. As the service is mainly orientated on selling, some information like route graphical representation and trip distance is not provided by service.

Train and Bus in Latvia – Android software

The “Train and Bus in Latvia” application for Android provides opportunity for user to save the schedule for selected routes and use it for informative purpose. The information provided by software is data from service 1188.lv and m.1188.lv (mobile version of 1188.lv). The screenshots of application could be seen on figure below (Fig. 2.)

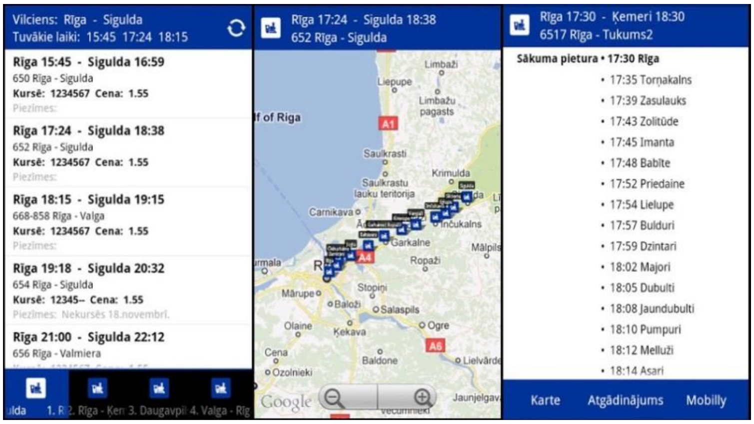

Fig.2. Screenshots of application.

Ldz.lv service

The Ldz.lv service is a portal of national Railway Roads. The webpage has a possibility to plan the journey by searching routes. The information which should be provided is: departure station, destination station, departure date and time. The service provides opportunity also to find the routes between not directly connected stations.

2.3. Parking and Automatic Payment

The Parking and Automatic Payment systems are not well developed in Latvia from point of view of using ITS. Only in capital of Latvia such services are introduced. There are two main parking operators "EUROPARK" Ltd. and "Rigas Saiksme" Ltd., who manages parking services There are number of examples of using ITS by both entities. "Rigas Satiksme" Ltd. manage on-street parking places, meanwhile "EUROPARK" Ltd. has a number of dedicated places for the parking. As example of ITS use following could be mentioned:

- on-line electronic boards on entrance, who informs visitors about number of free parking places in current parking;
- parking place reservation via the operator's webpage.

Both "Rigas Satiksme" Ltd. and "EUROPARK" Ltd. support no cash payments provided by MOBILLY Ltd. using Smartphone application and SMS service. In the same time in Riga it is possible to use RigaParking software developed by the "AmberPhone" Ltd. Also it is possible to use a smart card service provided by "NetCards" Ltd. for Riga parking.

There is a possibility to use a Park and Ride service in Riga. The Park and Ride was opened in December of 2012 and it is Free for a driver if he/she validates not less than two times an e-ticket for public transport.

2.4. ITS for Public Transport Management

ITS solution for public transport are rather fragmented in Latvia and mainly concentrated in Riga and Jelgava. The most developed solutions are related with use of the e-ticketing service in these cities. The introduction of the e-ticketing systems allows to follow the demand of passengers and use the data for more affective public transport routes planning in cities.

e-ticketing in Riga and Jelgava

E-ticketing system in Riga for public transport was implemented by the company "Rigas Karte" Ltd. The period of implementation lasted from January 2008 till April 2009. The system was presented and started to operate in April 2009. In frame of project the number of solutions were adopt and customization for own needs was performed. The reasons of implementation are following: no transport usage statistics available or it is not exact; lot of cash handling; fraud and theft. The implemented solution was based on Atlas ticketing solution provided by ACS Solution (XEROX Corporation). The implementation of the system was done with the goal to increase efficiency, quality, transparency and popularity of the public transport system by applying modern ICT technologies. Inhabitants are directly impacted by the solution as follows:

- No cash – no need to have and look for coins in full public transport. Everything is needed just to apply card to validator, even not taking card out from the bag or wallet.
- Ability to control costs on public transport – the use of personalized card allows to control costs on public transport.
- Different types of e-ticket, which meets user needs – there are a number of different e-tickets, this allows to create a very flexible options for passengers.
- Additional services included in e-ticket – as was mentioned above Atlas e-ticketing supports application of additional services inside e-ticket (at example schoolchildren identity card etc.).
- Intermodality – different types of public transport could be used with one e-ticket.

In the same time Jelgava city has implemented their own solution for e-ticketing, which is based on integration e-ticket for public transport in banks cards.

VBTS – Unified ticket sales system

VBTS – Unified ticket sales system, originally "Vienotā biļešu tirdzniecības sistēma" (VBTS) has been designed and is maintained in accordance with the 2 October 2007 the Cabinet of Ministers Nr.676 "Single public transport ticketing system (VBTS), booking and tracking system installation and maintenance procedures". The system goal is to provide online ticket purchase possibility in public transport vehicles and tickets booking functionality at any ticket office (ticket outlet other than a public vehicle) to any existing route network route, with some limitations for purchase of railroad tickets. It was planned that VBTS will service different public transport operators and different ticketing systems (Yatskiv et.al, 2015). The following list clarifies the planned scope of integration sources:

- Rail road – VIPUS
- Bus terminal stations – Baltic Lines
- Internet sales – Bezrindas.lv
- Regional, Intercity and Urban buses – onboard equipment by Nordeka Serviss.

The most important functions of VBTS defined (planned) by the Cabinet of Ministers are:

- Maintenance of registers - to collect and compile information on routes, fares (rates), public transport traffic etc. on intercity and regional routes. Currently, the registry information is up to date - VBTS is supplemented by a regional planning routes and routes data.
- Maintenance of ticket operations transactions – to receive online, process and update information about ticket sales, reservation and cancellation in ticket offices and public transport, as well as provide up to date information about the actual availability the tickets for purchase and reservation (warehousing).
- Telematics data processing – using online mode, to receive and processes information about installed peripherals on transport vehicles (global positioning, telematics equipment and cash registers) obtain information of bus current location and particular ticket sales coordinates.

Currently, data transmission is ensured for all intercity buses and semi - local regional bus services. Regional coaches are only partially equipped with the necessary telematics devices. The limiting factors to full telematics data processing are obsolete peripherals, on board point of sales (technical characteristics, hardware and software without the manufacturer's support, lack of communication module). Till nowadays, ticket operations transaction records are incomplete - no information on ticket sales received from the bus stations (using "Baltic Lines" system) and the Internet (www.bezrindas.lv). There are currently no warehousing functionality - the actual availability of the tickets for purchase and reservation. The bottleneck of the system is necessity of always online communication. Which by its nature is very sophisticated task, it also significantly complicates system infrastructure and support.

Bus terminals sales, accounting and management support system (Baltic Lines)

"Baltic Lines" is a bus ticket sales, route tracking and bus-specific process management support tool. That system was developed in 2003 for Riga International Bus Station needs. The developer company is "S Fabrica" Ltd.

Since 2006, the system began to be used in other bus station terminals. Currently, the "Baltic Lines" perform in 33 out of 35 Latvian terminals. "Baltic Lines" system provides possibility for customers to purchase tickets for the bus route services, where the starting point is a Latvian bus terminal station. As was analyzed previously, this option is about 40% of intercity and regional routes. "Baltic Lines" system interoperates with internet marketing site www.bezrindas.lv which extends tickets purchase options to internet.

Unified income and passengers accounting system (VIPUS)

VIPUS is ticketing system used in rail road network, operated by "Pasažieru Vilciens" JSC. The system was developed in 2006, based on the Baltic Lines system, developer - company "S Fabrica", which provides VIPUS and Baltic Lines compatibility. The system allows a purchase in any railway ticket office, for any rail route, between any two stations.

System provides possibility for purchasing of train tickets at railway stations and stop points, system also store conductors ticket sales made with handheld terminals and hand-prescribed tickets. The system base is the central data server, which performs data parameterization, configuration and data storage functions. The workstations communicate with the server at least once a day, for the mutual exchange of information. In addition, the system allows importing of data files and data from the non-system sales (with the hand tickets sold and terminal controllers listed in the ticket).

One of the objectives during implementation of the “VIPUS” was integration with "Baltic Lines" system to the extent that both systems could be selling all kinds of, but it was not being realized because of various sales strategies and changing legislative rules.

The system design does not include interaction with on-board equipment, so practically the available information regarding ticket sales, is those which were sold in bus terminal station, any purchase made in different location, is outside of the system scope. Currently, no information about sold tickets using the "Baltic Lines" system is transferred to VBTS, which contradict with public transport development plans.

Taking into account the hardware exploitation period, now it's time for the gradual renovation and changeover of the equipment, however, is a very complex problem to find alternative equipment matching system needs for future exploitation. These problems are caused by factors associated with the individual design program, in particular the adaptation of the system equipment, and system developer’s inexperience with similar programs development. Notwithstanding the above, VIPUS has in recent year’s significantly improved passenger revenue accounting and quality, as well as provided a significant cost savings compared to the previous ticketing system.

Demand modelling

Another example of ICT application in the area of public transport is related with demand modelling of the passengers. This example refers to the simulation model implemented in Vidzeme Region of the Latvia. System for public transport modelling in Vidzeme region was developed in frame of the project orientated on increasing of quality of regional public transportation service. The goal of the system is to offer an interactive, GIS-based, multimodal simulation tool for detailed, client-based analysis of public transit quality and planning of public transit infrastructure. The solution was implemented by Riga Technical University and Ltd “imink”.

The developed system helps to make decision on strategic and tactical levels about changes in public transport system in Vidzeme region. This allows to estimate different development scenarios of public transport system taking into account needs of Vidzeme region population, transport operators, municipalities and Vidzeme planning region.

By using developed system the integrated analysis could be done:

- Analysis of route network traffic intensity.
- Analysis of public transport stops availability.
- Analysis of settlement accessibility.
- Analysis of output results (number of transferred passengers, total costs, mileage etc.) in general.
- Analysis of output results for specific routes.

The developed solution considered as a useful tool for decision-makers in their efforts to evaluate alternative public transit scenarios and planning options.

2.5. Fleet Management and Freight

Fleet management and freight is a field there are primary the private companies are operating, as providers of the services for transport companies. There are a number of companies, who provides fleet management and freight services, the biggest are: EcoTelematics Ltd. and MapOn Ltd. Both companies provide the software and the hardware part of the fleet management and freight system.

3. Conclusions

The state of intelligent transport solutions in Latvia have been analysed in the paper, taking into account different subareas: Emergency Management and Incident Services; ITS for Traffic Management and Mobility; Parking and Automatic Payment; ITS for Public Transport Management; Fleet Management and Freight. Taking into account the technical and technological evolution of the new ICT tools in the field of ITS and current state of the ITS development in Latvia could be concluded that ITSs in Latvia remains still fragmented in what they offer in the geographical scope and the coverage of the different subtopics. The most developed subareas are: ITS for Public Transport Management and ITS for Traffic Management and Mobility compare to the rest. But still, even in these subareas there are a number of challenges related with modes of transport; rarely provide cross-border travel information. The next steps, for instance, in ITS for public transport are to be more integrated with the help of the same technological platforms: ticket validation systems, based on rechargeable and contactless e-cards, and real-time information system for all modes of transport. It is still not possible to buy a single ticket for a multimodal journey in Latvia and across national boundaries in EU. For many destinations, it is not possible to book an integrated ticket that includes both the long-distance part and first and/or last part of the journey. Integrated ticketing is a key part of an user-friendly multimodal transport system and a prerequisite for a seamless journey. The ability to travel by multiple modes of transport, while only needing to purchase one ticket for the whole journey, is a valuable incentive to encourage travellers to combine several modes of transport.

One of the important goals now is to implement the concept “Open Data” and automated fare collection systems. Data collected through the automated fare collection systems have applications on different levels: from network planning to network monitoring and the detection of irregularities. This data is valuable to observe the travellers’ behaviour, to estimate OD matrices and to infer the journey time.

Use of intelligent transport solutions in Latvia should improve efficiency, safety, quality and reliability of the transport service, reduce maintenance costs and offer possibilities of increasing revenues.

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A Comprehensive Analysis of the Planned Multimodal Public Transportation HUB

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Abstract

The research interest in multi-modal passenger transportation planning is growing and dealing with transport infrastructure projects a big number of different challenges have to be considered. Urban transport planning includes scientific and technical knowledge to actions in urban space. In recent years a lot of smart technologies have been promoted for urban problems solving. However, the European Regulation No 1315/2013 takes account of the fact that infrastructure projects need a certain involvement of public and private stakeholders to ensure the promotion of sustainable transport solutions, such as enhanced accessibility by public transport, telematics applications, intermodal terminals/multimodal transport chains, low-carbon and other innovative transport solutions and environmental improvements and the enhancement of cooperation between the different stakeholders. So, including the transport sustainability issues (such as network efficiency, cohesion and environment) in planning process is the obligate requirement for strategic transport planning.

The research presents an overview of the case study: planning decisions for the passenger network in Riga City in the frame of the Rail Baltic project – Riga central multimodal public transportation hub. Multi-modal transportation planning should have integrated institutions, networks, stations, user information, and fare payment systems; it is needed to consider all significant impacts, including long-term, indirect and non-market impacts such as equity and land use changes. One of the key-stone question in this case study - multi-modal transportation planning requires consideration of the factors that affect accessibility and whether they are currently considered in planning? The paper presents an integrated analysis in the area of planned transport node compiled from the individual partial studies and based on the desk research. Traffic on macro-level and transit mobility issues are the central aspect in this analysis.

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Keywords: Sustainable development, multimodal transportation, terminal, planning, accssebility, indicator

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1. Introduction

There has been a growth of interest in the concept of transportation planning of multimodality, typologies of hubs, interchange etc. Multimodal transportation uses the optimal efficiency as a goal and is defined as the complete transportation process, using at least two means of transport to create connection and transport together and, of course, a critical role is played by transport interchanges (hubs). Urban transport planning includes scientific and technical knowledge of the actions of the urban space. The integration of land-use planning and transport planning is as the keystone of a sustainable transport planning (Banister, 2008; Cervero et.al., 2009; Van Wee, 2013). As mentioned in (Litman, 2014) transport planners have started to apply Level-of-Service ratings to walking, cycling and public transit, and to consider demand management strategies as alternatives to roadway capacity expansion.

Including the transport sustainability issues in the planning process is the obligate requirement for the strategic transport planning; however, such integration is rarely present in practice (Te Brömmelstroet et.al., 2009, Heeres et.al., 2012). Different authorities in different institutional settings are usually responsible for transport infrastructure and spatial development. In infrastructure planning, government agencies usually are responsible for only a certain infrastructure mode: road, water, rail, etc., and develop often projects with limited scope. They focus on solving a concrete problem and applying a minimalistic approach oriented on formal requirements for public consultation. Spatial planning authorities often pay too little attention to the accessibility effects of their plans.

Regarding the link between multimodal interchanges and their impacts on land use in (Banister et.al., 2001) it was proposed that it is not direct if there is not a strong integrated development plan associated to the policy makers' involvement. Some cities have good business model based on PPP for developing their transport interchange, for instance, in (Cervero et.al., 2009) there is discussed an interesting example in Hong Kong - use the selling of land properties to develop the transit intermodal hub.

Many researchers now could try to analyse the integrated land-use plans offering new urban facilities and their related value due to the evolution of the transport city-hub (Heddebaute et.al., 2014). There are many research projects during the last decade: City-HUB (Cityhub-project.eu, 2016), NODES (Nodes, 2016), CLOSER (Project CLOSER, 2016) etc. where its' spotlight was passenger interchange, city-hub or terminal. As the results the typologies and guidance, set on best practices were developed and disseminated. City-HUB aims to make urban interchanges more accessible to all users. The approach is integrated, covering the different aspects of an urban interchange in order to increase the use of public transport (PT), improve the efficiency and propose a new business model (Cityhub-project.eu, 2016).

In (Kenworthy, 2006) author discussed planning and decision making for sustainable cities and sets out ten critical responses to the challenge of changing the nature of urban development to a more ecological, sustainable model, which suggests that sustainable urban form and transport are at the core of developing an eco-city. The author suggested that the main one from ten key dimensions into four critical "Sustainable Urban Form and Transport" factors is "decision-making process which should be sustainability-based, integrating social, economic, environmental and cultural considerations as well as compact, transit-oriented urban form principles".

This paper is devoted to the multi-modal transportation planning in Riga. The decision making process should involve integrated institutions, networks, stations, user information, and fare payment systems and consider all significant impacts. The authors offered the way the authorities could move the urban transportation system (UTS) to sustainability and to study a particular aspect of decisions on the passenger planning network in the city of Riga in the frame of the Rail Baltic project – Riga Central Multimodal Public Transportation Hub. The main question in this case study – how multi-modal transportation planning requires evaluation of factors affecting accessibility and how they are currently considered in planning. Part 2 contains a review of the aims and main possible impacts of the Rail Baltic project; also the list of stakeholders of this object is determined. Part 3 includes the discussion of the results of the questionnaire survey about significance (weights) of sustainable transport indicators in Riga and descriptive statistics of the results. The most important aspect of sustainability transport development for Riga Hub planning – accessibility is revised and different approaches to measure are analysed in part 4. Part 4, also determines the most controversial issues of the planned new Hub and set methodology for the accessibility measures analysis.

2. Riga Central Multimodal Public Transportation Hub in the context of the Rail Baltic project

Riga, as the capital of Latvia, is the central node of the country' transport star-designed network. As defined in the Riga Sustainable Development Strategy (Riga Strategija 2030, 2016) the key public transport infrastructure element will be Riga Central Railway Station (RCRS), which will provide multimodal functions. The significance of this station is increased in context of largest infrastructure project in the Baltic Sea Region - Rail Baltic. The goal of this project is to integrate the Baltic States in the European rail network. Latvia as well as the other Baltic States still uses the rail width of 1520 mm, and one of the reasons why it is necessary to reconstruct is because the most part of the EU countries use the track width of 1435 mm (Railbaltica.info, 2014). Riga shall be the only Rail Baltic stop in Latvia, which will be conveniently linked with transport modes for the route change to Airport Riga. RCRS shall be reasonably linked with the international bus station, the largest bicycle parking lot shall be established here.

The Riga Municipality has the ambitious plan to reconstruct this node to Riga Central Multimodal Public Transportation Hub (RPTH), that will merge in a single infrastructure international and domestic passenger railway traffic, Latvian regional, local and Riga City public transportation traffic, as well as personal transport access point and individual migration. RPTH integrates the European gauge railway line Rail Baltic and covers Riga Central Station area, related public transportation terminals (including Riga International Coach Terminal), stops, individual transport access, stoppage and parking sites, as well as infrastructure linked with the RPTH related to individual migration (Ministry of Transport, 2016). The decision is complicated because there are many stakeholders involved. The European Regulation No1315/2013 (Eur-lex.europa.eu, 2016) takes into account the fact that infrastructure projects need a involvement of public and private stakeholders to ensure the promotion of sustainable transport solutions, such as: enhanced accessibility by public transport, telematics applications, intermodal terminals/multimodal transport chains, low-carbon and other innovative transport solutions and environmental improvements and the enhancement of cooperation between the different stakeholders.

According to the approach in passenger transport typology that was proposed by the CLOSER (Project CLOSER, 2016) the RPTH could be classified as national hub, because it is a railway station, that is connected with other terminals at national or international levels. National authorities are interested in terminal, however under the umbrella of national policies and governmental companies or administrative bodies most of the times own and/or operate the hubs, although private actors may also get involved. Rail Baltic is still at an early planning and design stage – holding companies are being established, final railway route is not decided upon, further planning and design stage works are expected to be procured in 2017. A broad level political agreement has been reached, and the research process is still active for the planning of project implementation. That's why it is important to plan and create a multimodal transport hub with only aim to improve the quality of Riga and country PT system. The quality of all aspects of integration should be viewed from this position, but the difficulty – the large quantity of stakeholders are involved: public (Ministry of Transport; Latvian Railway; Riga Central Station; International Airport; Riga City Development, Traffic Departments; Road Transport Administration) and private (International Coach Terminal; Passenger carriers; Owners/managers of nearby infrastructure objects).

On the other hand, multimodal transportation is a kind of integrated operation process, it is a combination of modern organization means and single transportation mode and it has important improving transportation service quality by researching the decision of multimodal transportation scheme in the process of transportation. The NODES projects' overall objective was to build a toolbox to help cities in the design and operation of upgraded/new urban interchanges, as a way to provide greater support, services and satisfaction to the travellers, users, interchange operators, and to societal and economic actors that depend on the efficiency of interchange operations. On the basis of a state of the art a set of criteria and performance indicators were developed in this project. The general objectives based on the triangle of stakeholders' goals (financial, environmental and societal) are the following: (1) enhance accessibility and integration; intermodality and liveability; (2) increase safety and security conditions; economic viability and costs efficiency; environmental and energy efficiency; (3) stimulate local economy.

The general objectives can be translated in needs of the interchange stakeholders, more specific individual customers of the public transport, the citizens that benefit from a well-functioning PT and its interchanges (Hoeverna et.al., 2014). A common platform for the integration of different interests should be to make the multimodal transportation more attractive, in the requirement of planning process to optimize the transfer and waiting time.

3. Sustainability transportation indicators and their significance for Riga transport system

The main aim of the new Riga multimodal hub planning stage is to develop RPTH concept (project) that guarantees a more efficient, effective and inclusive urban transport system for travellers and citizens. Thus, at the stage of initial planning it is absolutely necessary to analyse and evaluate the effects of the planned changes, allowing improving our understanding of all elements of new project and be sure that the multimodal hub provides a user-friendly clean, energy-efficient, safe, secure and intelligent transport for all users. The decision making framework should include the holistic approach to analyse all aspects of sustainability transportation.

Firstly, it is necessary to create a comprehensive system of indicators and to evaluate which of them are defining the urban sustainable development and how they refer to the transportation sector. There are many scientists working in this direction, and different set of the indicators are still being discussed (Buzási et.al., 2015; Alonso et.al., 2015 etc). However, sustainable transportation indicators (STI) should be adapted to concrete conditions and state of the UTS, because each transport system has it specific and the weights of STI in analysis may be different.

The face to face questionnaire survey about significance (weights) of STI for Riga transport system was conducted in this research. The indicators used for it (see Table 1) have been proposed in the SUMMA project (SUMMA, 2003). Respondents were offered to assess each of the indicators of importance using Likert scale: (5) – Very Important; (4) – Important, (3) - Essential, (2) – Rather, not important, (1) – Not important.

Table 1. The questionnaire "Assessment the importance of sustainable transport issues for Riga Transport System" and results analysis

N	Criteria	Indicators	Min	Max	Mode*	Median	Sum
1	Accessibility	Access to public transport	3	5	5	5	48
2		Access to basic services	3	5	5	5	50
3		Accessibility of origins and destinations	3	5	4	4	45
4	Health and safety	Accident-related fatalities and serious injuries	1	5	-	3	33
5		Exposure to transport noise	2	5	3	3	38
6		Exposure to air pollution	2	5	3	3	36
7		Walking and cycling as transport means for short distances	2	5	3	4	41
8	Cost effectiveness	Energy efficiency	1	5	3	3	35
9		Generation of non-recycled waste	1	5	-	2	36
10		Public subsidies	1	4	2	2	26
11	Impact on competitiveness and generation of wealth	Gross value added	1	4	3	2	25
12		External transport costs	1	4	3	3	31
13		Benefits of transport	1	4	-	3	36
14	Consumption of natural capital	Land take	1	4	3	3	30
15		Consumption of solid raw materials	1	5	-	3	32
16		Damage to habitats and species	2	4	-	3	34
17	Production of pollutants (local and global)	Emission of greenhouses gases	1	4	3	3	31
18		Emission of air pollutants	1	4	4	3	31
19		Runoff pollution from transport infrastructure	2	4	3	3	36
20		Discharge of oil and waste at sea	1	4	3	3	32

* where mode exists

The focus group was presented by representatives of municipalities and researchers. Despite the small number of respondents (totally 11) it should be noted, that they are knowledgeable and reliable experts in this matter. The descriptive statistics of estimations made by experts are represented in Table 1, shows that for Riga city more important sustainable issues concerning the accessibility and less important environment questions. Of course, it is needed to estimate the indicators' weights on the basis of more representative samples and citizens' opinions. Riga is divided into 58 districts, the development of these areas is not even and the inhabitants of each of them have their attitude towards mobility and sustainability. For instance, residents of district located near the port in favour of the noise and air pollution, while others are not satisfied with the availability of public transport. This research are necessary to carry out in all districts for more information about the sustainability indicators and then analyse how the planned new multimodal HUB influenced on it.

Then, it is important for research to determine the most controversial issues of the planned new Hub and set methodology for accessibility measures analysis. The suggested approach requires the measuring actual transport system accessibility and modelling the planning transport system accessibility. The decision-making tool should include the tool for estimating the functioning of the urban transport system now and evaluating infrastructural project ex-ante.

The list of significant changes of PTS in the project of RPRH is the following:

- ✓ Network changes: street directions and new streets creation (Dzirnavu iela connection with Krasta iela; new street creation in Kļavu iela, Turgeņeva iela one lane for public transport).
- ✓ Junctions' reconstructions: traffic lights regulation for providing Level of Service in Marijas iela–13. janvāra iela–Satekles iela; new signalling (including traffic lights and horizontal signaling) in 13. janvāra iela; signalized junction coordinated with TrolleyBus&Tram lines in Abrenes–Turgeņeva iela.
- ✓ Trolley bus network: new schedule and new line (Turgeņeva iela one-way street).
- ✓ Tram network: new schedule, new line through Dzirnavu iela, new provision of electrical system for Tram line, new Tram station and widening from Dzirnavu iela to Turgeņeva iela.
- ✓ City buses & minibuses network: new schedule, city Buses Depot (new Access from Dzirnavu iela from North & South City; safety turn proposed from Satekles iela, Timoteja iela).
- ✓ International Coach Terminal configuration: to moving the existing Terminal to the new HUB; international coaches interchange dislocation in the 1st level under railway; access adapted to new way disposed in Elizabetes iela etc.
- ✓ Private cars (kiss&ride/car parking): integrated option with Public Transport/Taxi Parking/Kiss& Ride; Taxi Parking disposed in the North to provide a unified exit for passengers in the Hub Entrance.
- ✓ Pedestrian Crossings.
- ✓ Bicycle network. Will be created a lot of new bicycle lines.

For holistic approach to estimate the functioning of the urban transport system and evaluate the expected outcome of new infrastructures and services it is necessary: to define the accessibility indicators; to develop the simulation model; to design and execute the simulation experiments to evaluate the proposed solutions in the aspect of sustainability issues and maybe to discriminate between alternative solutions for the changes listed above.

4. Accessibility as main sustainability transportation issue for RPTH planning and decision-making

As the questionnaire results showed the accessibility of Riga Transport system is one of the most important indicators, therefore the main aspects that should be analysed in decision making at the stage of RPTH planning are measures of accessibility before and after reconstruction. The question is – Should spatial and transport planning be better coordinated to match transport demand to access needs?

Accessibility can be defined as the ease with which an individual can 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). The concept of accessibility thereby goes beyond the framework of the transport system and its purely temporal dimension, associating it with a spatial dimension. Accessibility should reflect the spatial organization and the quality of the transport system that provide individuals (alone or in groups) with the opportunity to participate in the activities located in different parts of the region (Geurs et.al., 2004). In (Litman, 2012) provides an overview of literature into 'accessibility', found different factors that affect accessibility: transportation demand, mobility, transportation options, user information, integration of the transport system, affordability, mobility substitutes, land use factors, transport network connectivity, roadway design and management, prioritization and inaccessibility. He concludes that there is no single indicator to capture accessibility. In fact it depends on the goal of the study how accessibility should be measured. According to the definition the level of accessibility depends on the location of activities, quality and quantity of infrastructures, and needs of people and companies. The level of accessibility has an impact on the economy, because a well- functioning transport system in combination with the land- use system is a condition for economic development. Accessibility is not only relevant for the economy but fulfils a social role (Wee et.al, 2013).

In (Litman, 2015) discussed that STI 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). In (Litman, 2013) he suggested that accessibility-based planning recognize the next factors that affect accessibility: mobility, the quality of transport options, transport network connectivity, land use accessibility - accessibility-based planning.

Transport accessibility can be analysed by different methods and in recent years a lot of smart technologies were promoted for it. Accessibility impacts of transport projects can be assessed using transport modelling for planning sustainable mobility. So, the transport models should at least be able to provide accessibility as an output, or results with which accessibility measures can be calculated. Concerning the indicators of accessibility in (Geurs et al., 2013) classify it on the following accessibility measures: infrastructure-based, location-based, person-based and utility-based. Infrastructure-based measures are related to analysing the TS itself (length of networks, level of congestion or speed). The location-based measures analyse the accessibility of locations at a macro level. The person-based measures relate to the accessibility at an individual level. Utility-based analyse the benefit people derive from access to spatially distributed activities (Jong et al, 2005). The level of detail of the indicator depends upon the level of detail of the transport model used. Other typologies of accessibility measurements identify three broad classes of indicators: cumulative opportunities, gravity-based, and utility-based (Geurs et.al., 2004).

Accessibility is affected by many factors like mobility, quality and affordability of travel options, mobility substitutes, but in term of multimodality - connectivity of the transport system and land use features are most important. Geurs examined accessibility under the view of combination of transport modes and the easiness to make a combined transit trip (Geurs et al, 2001). The quality and location of a transport terminal, as well as the connection between links and modes, also affect the accessibility level of the terminal (Litman, 2012).

The main focus is accessibility for the passenger when changing from one mode of transport to another. For ex-ante analyses, accessibility indicators are basically summaries of modelling outputs based on travel times between pairs of nodes. Using the access time to/from city centre measure, accessibility is calculated based on the shortest journey time during the morning/evening peak hours by PT from the nearest node (station) in the network. The shortest possible journey time might be achieved by using one service or through an interchange between different services whether services are provided by the same or different operators with the same or different transport mode.

In this study, to identify the aspects of planning efficient operated transportation hub we offer to use groups of indicators for accessibility assessment, based on the list offered in (de Stasio et.al., 2011):

Accessibility as outcome of two functions and determined for area *i*:

$$A_i = \sum_j g\left(W_j\right) f\left(c_{ij}\right) \tag{1}$$

where W_i -attractiveness to be reached in area j and c_{ij} the "effort" for reaching area j from area *i*.

The functions $g\left(W_j\right)$ and $f\left(c_{ij}\right)$ are called "activity function" and "impedance function", respectively. According to the form of the functions, different types of accessibility indicators are calculated (de Stasio et.al, 2011):

- *Travel cost*, where $g\left(W_j\right)$ has value "1" or "0" depending on the destination zone ("1" for zones where attractiveness exceeds a given threshold) and the impedance function is travel time or travel cost itself.
- *Daily accessibility* where $f\left(c_{ij}\right)$ is expressed in the terms of travel time and only destinations within 24h (or another threshold) are considered.
- *Potential accessibility*, where the impedance function is generally nonlinear, (e.g. exponential), also the activity function may take account of agglomeration effects, economies of scale and therefore can be nonlinear.

Interconnectivity Ratio proposed in (Krygsman et.al., 2004) is the proportion of access and egress time to/from the network to the total trip travel time and calculated for area *i*:

$$IR_i = \sum_j (AT_{ij} + ET_{ij}) / \sum_j TotT_{ij} \tag{2}$$

where AT_{ij} -access time to the network for reaching area j from area I, ET_{ij} egress time from the network for reaching area j from area I, $TotT_{ij}$ total travel time for reaching area j from area i.

This indicator stems from the consideration that access and egress stages are the weakest part of a multimodal chain and their contribution to the total travel disutility is often substantial.

Closeness Centrality is applied to multimodal transport, derived from the graph theory and provide measures of nodes "centrality" within a graph, i.e. its relative importance. It defined by the inverse of the impedance between the node *i* and all other nodes in the network:

$$CC_i = (N-1)/\sum_j Dist_{ij} \tag{3}$$

where $Dist_{ij}$ -impedance between nodes *i* and *j* ($i,j \epsilon N$ and $i \neq j$) and N – all nodes in the network.

Closeness Centrality increases when the impedance between the zones is reduced, but does not provide any specific information on how the existing interconnections work. This aspect can be considered in the definition of the impedance and can be measured in alternative ways: distance, travel time, travel cost, etc. Other measures of impedance where e.g. a penalty for transfer time is applied could be used to emphasize the role of interconnectivity.

The approach requires using the offered measures above the measuring actual TS accessibility and modelling the planning TS accessibility. At that moment, multidimensional analysis of the current state of accessibility and the future state couldn't be analysed because of the lack of data about all the needed aspects for measures calculation.

6. Conclusions

This paper has conducted the decision problem of multimodal transportation hub in context of sustainable issues and the results provided the methodology which can be used for the Riga Central Multimodal Public Transportation Hub project decision making. The approach to incorporate sustainability considerations in the transport planning problem is presented. This paper suggests that the changes in the transport system lead to changes in accessibility issues and it has an impact upon the transport system environment and, of course, sustainable development. In many countries and cities improving accessibility there is an important government goal. In this study, an effort was made to identify the aspects of analysing planning efficient operated transportation hub that promote sustainability.

To quantify the effects of a change in the transport system, transport modelling should be applied. The next steps in research will review the data which need to model and to assess the impact of changes in planned infrastructure. The list of significant changes in PTS was determined and it is the basis for future modelling and analysing the suggested variants (advantages and disadvantages of the planned decisions). Decision makers should analyse the sufficiency of resources for performing the timetable of the PT traffic, the convenience of their allocation, access and egress stages in multimodal trip etc. The authors conclude that it is important and necessary to consider the development of transportation projects from sustainable transportation perspective only; to choose from the STI list the significant ones for a concrete city and to use them for the assessment of the project outcomes.

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Optimization of Ground Vehicle Movement at Aerodromes

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Abstract

This paper deals with the process of management of ground vehicle movement at aerodromes. It is a huge challenge to provide the growth of airport capacity which is required due to the increasing number of passengers and goods flow, without good management in aircraft operations, including the standing time of aircraft on the ground. In the first part of this Article, the current trends in the development of airport ground processes and control techniques are considered. Official IATA (International Air Transport Association) documents and scientific publications are the source of new ideas in this field. In the second part of this Article, the use of computer simulation is prescribed for the purpose of testing new methods of transport movement control. Also, the methodology of the simulation model, which has been designed to optimize work flows arising during movements of airport ground vehicles, is demonstrated. The developed model is a test bed for conducting experiments, which may help in finding more effective airport ground processes control techniques. A similar model can be created for any other airport, on the basis of which is scheduled to verify the possibility of technical implementation of new control technologies of ground vehicles.. The practical implementation of these new technologies should be solved taking into account the requirements of ICAO and IATA, in particular ICAO Annex 14.

Keywords: A-SMGCS; Airport movement area; Ground handling; Optimization; Simulation

1. Current trends in the development of airport ground processes control techniques

The innovations in airport design are created for the provision of services in aviation. The service providers in aircraft operations usually focus not only on the quality of the service, but also on the efficiency. The innovation in

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airport design involves complex predictions and involves a high degree of competition and aviation equipment development, with new methods, tools and materials, with sustainable technologies and well organized airport infrastructure. It is particularly important, for reasons of passenger security and safety, that all aspects are considered for effective air operations and also for effective ground handling.

There is a huge demand for increasing airport capacity, caused by the increasing number of passengers and goods flow. Air travel has become accessible to billions more travelers in recent years. In 2012, 2.8 billion passengers used air travel (IATA Vision 2050 Report, 2011). According to the IATA 2050 report, it is expected that 16 billion passengers and 400 million tons of cargo will be transported by aircraft in 2050. It is a huge challenge to provide the growth of airport capacity which is required due to the increasing number of passengers and goods flow, without good management in aircraft operations, including the standing time of aircraft on the ground.

There are many analyses and much research regarding this subject and many publications have been issued in this field. Some of them are legislative acts only, and others are NOTAMs (Notice(s) to Airmen) and instructions to all operators.

Bonnefoy et al. (2010) carried out research entitled ‘Evolution and Development of Multi-Airport Systems’, the core of which is the solution that creates “Multi-Airport Systems”. The multi-airport system is defined as a set of two or more significant airports that serve commercial traffic within a metropolitan region. But with this solution they stated that the congestion problem at the three major airports in New York could also drive the emergence of a new secondary airport. However, the development of a multi-airport system poses several challenges in terms of planning and development.

De Neufville (2003), Professor of Engineering Systems and Civil and Environmental Engineering at Massachusetts Institute of Technology, also carried out research in this area and published his article ‘Airports of the Future: The Development of Airport Systems’. Worldwide development presents some emerging trends towards focused specialization in airport operations, and the major types of airport are there defined:

a. Intercontinental airports, serving the global international passenger traffic, functioning 24 hours a day, 7 days a week;
b. Cheap Fare, short haul airports, that strive to be inexpensive, to match the demands of their clients; and
c. Cargo airports, dedicated to serving integrated freight operators.

Price et al. (2013) issued an article ‘Design led innovation: Shifting from smart follower to digital strategy leader in the Australian airport sector’. The article described the proposed future aerotropolis airport model and argues that airports act as cities; they are home to people, businesses, industries, and are a pivot point for economic growth. A cultural and organizational transformation within the airport sector supported by business model innovations will be required to accompany such a monumental shift toward the future operation of airports.

As stated in the law and regulation of aerodromes, Abeyratne (2014), there are five main factors which play major roles in improving airport capacity:

a. Integration of GNSS use;
b. Integration of arrival/departure/surface management;
c. Optimization management;
d. Improvement of surface surveillance;
e. Airport collaborative decision making.

It is impossible to improve items number (b) and (d) without good management and optimization of ground vehicle movements and operations.

On the other hand, the accidents and incidents which take place at aerodromes involving ground vehicle operations and impact with aircraft by these vehicles, are rapidly increasing.

ICAO and EUROCONTROL defined the “Advanced-Surface Movement Guidance and Control System” (A-SMGCS) to ensure the safety and the efficiency of surface traffic at the airport movement areas (runways, taxiways and apron area).

The most extensive researches were provided by a Portuguese team of scientists, Casaca et al. (2008). They explain that the present level of technological development in the information and communication technologies allows the definition of a low cost platform for the vehicle navigation component of A-SMGCS, and present good ideas regarding how to use and integrate all the known communication network systems like WiFi, TETRA, CDMA and WiMAX, to optimize ground vehicle movements within the local area network.

Gonzalez et al. (2013) and a group of researchers issued a publication in 2013, where they stated that the optimization of future ground operations for aircraft cannot be understood without the study of the main platform, the Sky. For said purpose these two projects stand out; Next Gen and SECAR.

The Next Gen Air Transportation System, (Next Gen), aims to move America's air traffic control system from the current ground based system to a satellite based system with GPS technology. They assume that when dealing with airport operations, some points override others; they grouped these points in the following way:

a. A-CDM (Airport Collaborative Decision Making)
b. Unambiguous communications
c. Runway entrance control
d. No confusing lights • Less stop and go
e. Continuous taxi speed • Improved controller efficiency
f. Optimizing the use of available infrastructure
g. A-SMGCS (Advance Surface Movement Guidance and Control Systems).

This research dealt only with aircraft departure, runway occupation and holding time. They looked at the optimization only from an aircraft point of view, and disregarded the other conditions surrounding it.

Evertse et al. (2015) also carried out research in real-time airport surface movement planning and minimizing aircraft emissions and fuel burn. They used mixed-integer linear programming (MILP). The MILP model, as implemented, permits the tool to refresh the total taxi planning every 15 seconds, allowing response to unforeseen disturbances in the traffic flow. However, they took into consideration only the real-time taxi movement planning and optimization of taxing time. Again they ignored all other inputs that could affect this process.

Augustyn et al. (2015) started to study the problem of optimization and management of ground handling processes and proposed that the ATC operator takes a supervisory role only. Ground-based processors will send all the necessary information to the aircraft. They believe that this technology, which uses digital data link and real-time planning, can automatically and independently recognize and preplan. The function of ATC is then only to monitor the current operations and would intervene and rectify problems as required, in the event that they occur.

Zepra Eterprice Solutions (Airport Visualizer) produced new computer software called 'Airport Visualizer'. This software is already operational at Ataturk International Airport, Istanbul. This computer program, from our point of view, is more effective as far as it is works not only with aircraft, but it also takes into consideration ground vehicle movements.

The prerequisite of this software program is the transparency and visibility of all vital processes. The Airport Map, fully and seamlessly integrated to all of the airports' resource management and planning systems, provides this vital information tool, not only for the ground handlers' motorized GSE, e.g. tractors, loaders, GPUs etc., but also for all motorized vehicles used in ground operations – plus all non-motorized equipment and assets such as dollies, ULDs or palettes. The user of this fleet management solution will be able to monitor and control the operational effectiveness of all mobile assets on a single screen and benefit from real-time data and mission critical reporting.

The object of our research is all vehicles operating on the aerodrome, including aircraft, servicing vehicles, catering vehicles, loading vehicles, trucks, human movements etc. Fig. 1 shows such vehicles involved in the servicing of aircraft.

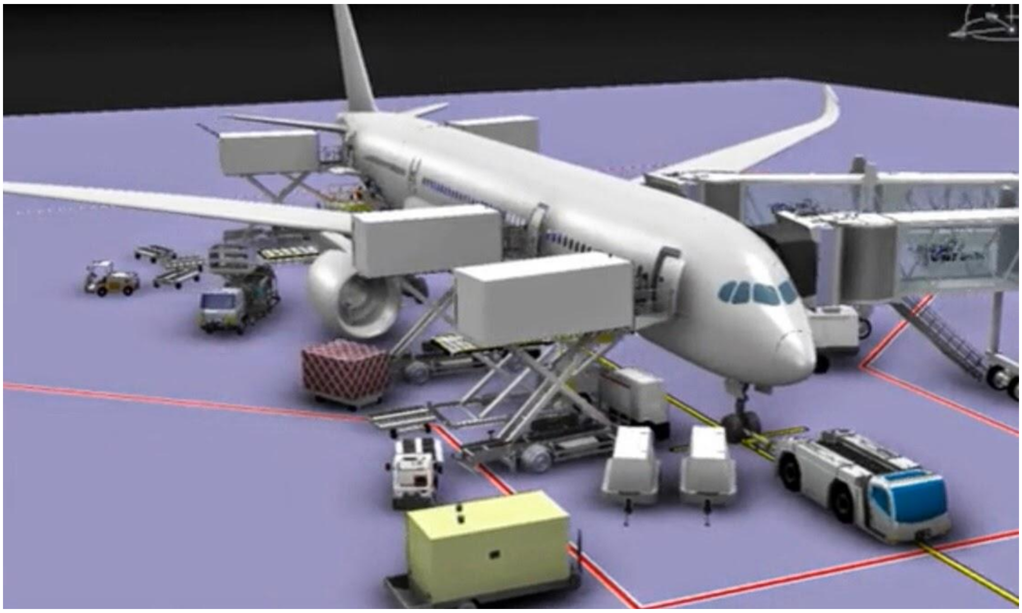

Fig. 1. Vehicles involving in aircraft servicing (by A350 terminal servicing and handling tests).

2. The use of simulation for the study of surface transport functioning

New technologies provide a wide range of data collection methods:

- Positioning system sensors, like GPS sensors and peeling system.
- Video information. Using special intelligent programs, which transfer video images into event logs. For example, from a video image, the program can set a protocol about trolley No. 20 reaching point x at time 21h34m12s. This program may be a type of Real-time Transport Protocol (RTP) (2003).
- Interpretation of information gathered from various elements of the system using various sensors.
- Humans manually enter information regarding the state of each system element via input devices.

In such circumstances new opportunities open up, to organize effective control of surface transport operations. For the purpose of testing new ideas in transport movement control, a simulator is used. A wide simulation experience has been accumulated in the field of designing and reengineering of container terminals. We can use the article of Liu et al. (2011) and Yang et al. (2014) where they analyzed vehicle movement problems on a container terminal based on simulation, as an example. Dzikus et al. (2010) carried out research and issued a publication related to the optimization of aircraft ground movement. During the research they used modeling and simulation, but they looked only at the aircraft itself, and disregarded the other items which can interfere with it. An article issued by Brandau and Tolujevs (2013) presents us the possibility of using an imitation model to generate streams of events, which are related to operation of airport surface transport. As a result of the accumulation of information about such events, a dynamic database is formed. This database reflects the current state of all objects involved in the aircraft maintenance processes.

In Fig. 2 below, we consider a model that is similar to the model described by Brandau and Tolujevs (2013).

The airport model displays three stands for aircraft (St) and a warehouse for goods (W). The goods are ULDs (Unit Load Devices), which are standard containers and pallets used on aircraft (FLZ). The transport of the ULDs on the airport ramp is provided by tugs and dollies (trailers). Tugs tow the dollies, which have the ULDs loaded on them. Special transport routes and areas are defined for the tugs, e.g. tug and dolly pools, garage and service station. In Fig. 2 the spatial structure of the airport can be visualised.

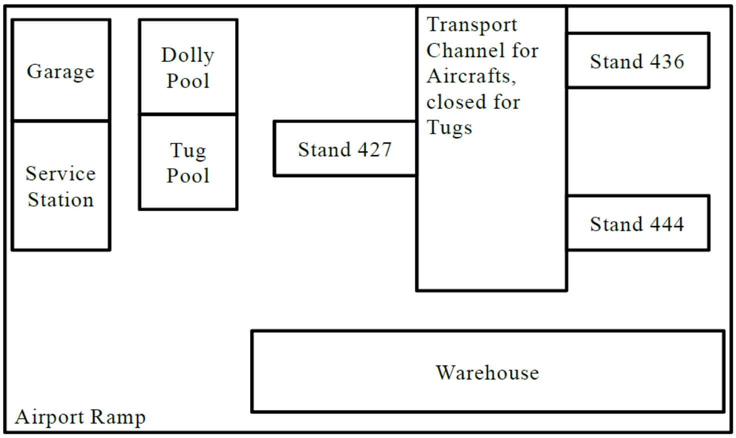

Fig. 2. Spatial structure of the airport ramp.

To identify connections between the object types, all relationships must be defined. The relationship “contain” is based on the object class “complex object types” and is shown on Fig. 3 below.

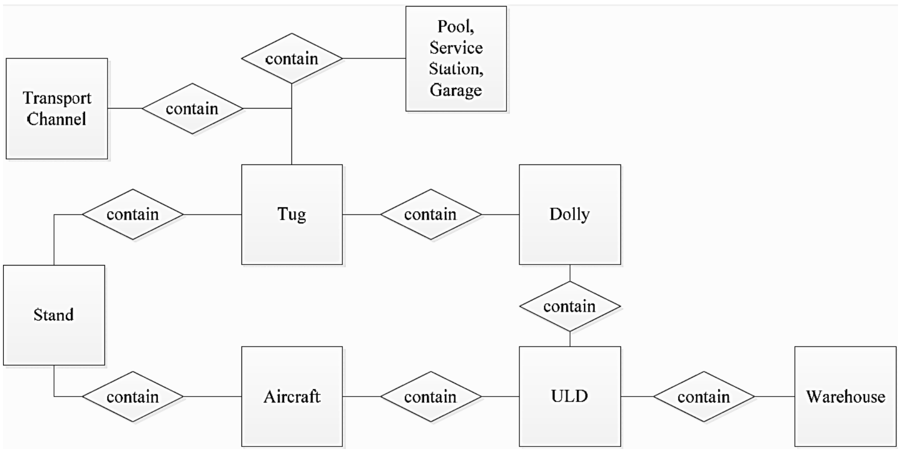

Fig. 3. Relationship “contain” for the application example.

For all complex object types, the capacity which is temporally constant is described as “Master Data” in Table 1.

Finally, the structure of the data for all objects is determined. For the application example, the structure is shown in Table 2. It can be seen that for the object type “ULD” the attribute “Content” is omitted. This is because ULDs are not complex object types. Also, for the stationary object types, the attribute “Location” is not necessary.

The model has been designed to generate event streams which arise during arrival and departure of the aircraft, as well as all movements of the moving objects, which include Tugs, Dollies and ULDs. Table 3 shows a sample of the protocol of the events associated with three specific objects FLZ1, TUG1 and DO1. The full protocol, in which the whole work process of the airport, for 8 hours of operation, are presented, and contains thousands of events relating to all those static and moving objects shown in Table 1.

As a result of the implementation of each event in the system, the state of one, or multiple objects changes simultaneously. Table 4 presents a sample of the protocol of the states for the same previously mentioned three specific objects FLZ1, TUG1 and DO1. The number of records regarding the states is greater than those of the events, because a single event often causes a change in the state of multiple objects. For example, when moving a single ULD from the aircraft to a Dolly, the location of this ULD changes, as well as the content of the aircraft and that of the Dolly.

Table 1. Master Data of complex object types.

Object Type	**Object ID**	**Capacity**
Dolly	Dolly1,…,Dolly40	1 ULD
Tug	Tug1,…,Tug10	4 Dolly
Stand	St427, St436, St444	1 FLZ
Transport Channel	Way St427-W, Way W-St427, Way St436-W, Way W-St436, Way St444-W, Way W-St444	4
Warehouse	W	250 ULD
Pool	TugPool, DollyPool	10, 40
Service	Station GS	3 Tug
Garage	G	3 Tug

Table 2. Structure of the state data off all object types.

Attribute	**Object type**									
	ULD	FLZ	Tug	Dolly	Stand	Transport Channel	Warehouse	Pool	Service Station	Garage
ID	X	X	X	X	X	X	X	X	X	X
Time	X	X	X	X	X	X	X	X	X	X
Location	X	X	X	X						
Status	X	X	X	X	X	X	X	X	X	X
Content	X	X	X	X	X	X	X	X	X	

Table 3. Extract from the model event protocol.

Timestamp	ID	Event	Parameter
	Aircraft FLZ1		
12.10.2015 23:00:00.0000	FLZ1	Arrival	St427
12.10.2015 23:00:00.0000	FLZ1	Start Unloading	
12.10.2015 23:01:00.0000	FLZ1	ULD out	AAY
12.10.2015 23:02:00.0000	FLZ1	ULD out	AAY
. . .			
12.10.2015 23:15:00.0000	FLZ1	End Unloading	
12.10.2015 23:15:57.8400	FLZ1	Start Loading	
12.10.2015 23:16:57.8400	FLZ1	ULD in	AAY
12.10.2015 23:17:57.8400	FLZ1	ULD in	AAY
. . .			
12.10.2015 23:30:57.8400	FLZ1	End Loading	
	Tug TUG1		
12.10.2015 23:04:00.0000	TUG1	Dolly in	DO1
. . .			
12.10.2015 23:04:00.0000	TUG1	Departure	Way St427-W
12.10.2015 23:04:58.9200	TUG1	Arrival	W
	Dolly DO1		
12.10.2015 23:00:00.0000	DO1	Arrival	St427
12.10.2015 23:01:00.0000	DO1	ULD in	ULD1
12.10.2015 23:04:00.0000	DO1	Departure	Way St427-W
12.10.2015 23:04:58.9200	DO1	Arrival	W
12.10.2015 23:05:28.9200	DO1	ULD out	ULD1

Table 4. Extract from the model state protocol.

ID	From the time	Location	State
Aircraft FLZ1			
FLZ1	12.10.2015 23:00:00.0000	St427	Waiting
FLZ1	12.10.2015 23:00:00.0000	St427	Unloading
FLZ1	12.10.2015 23:15:57.8400	St427	Loading
FLZ1	12.10.2015 23:30:57.8400	St427	Ready
Tug TUG1			
TUG1	12.10.2015 23:00:00.0000	St427	Stands with 0 Dollys
TUG1	12.10.2015 23:04:00.0000	St427	Stands with 4 Dollys
TUG1	12.10.2015 23:04:00.0000	Way St427-W	Drives with 4 Dollys
TUG1	12.10.2015 23:04:58.9200	W	Stands with 4 Dollys
TUG1	12.10.2015 23:08:58.9200	Way W-St427	Drives with 4 Dollys
TUG1	12.10.2015 23:09:57.8400	St427	Stands with 4 Dollys
Dolly DO1			
DO1	12.10.2015 23:00:00.0000	St427	Stands Empty
DO1	12.10.2015 23:01:00.0000	St427	Stands with ULD1
DO1	12.10.2015 23:04:00.0000	Way St427-W	Drives with ULD1
DO1	12.10.2015 23:04:58.9200	W	Stands with ULD1

3. Conclusion

The developed simulation model is a “test bed“ for conducting experiments, in which it is possible to change the type of the monitored events. The efficiency of the decision-making procedures during the process of managing the surface transport depends on the level of detail of event monitoring. Potentially, there are set in two tasks defined:

- Firstly, 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.
- Secondly, 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.

The experiments with the model should help to choose the control methods of the surface transport, which in turn will give the following positive benefits:

- Increased vehicles’ safe movement at the aerodrome, owing to automation of all processes and which are under real-time control.
- Increasing the productivity of the system (logistics index), due to minimizing of time lost during aircraft servicing. Also, this system can be linked to the ATC system, and in case of any delay or change in aircraft schedule, all systems on the ground will react in a timely way and adjust itself in order to accommodate the new aircraft departure time-slot.
- Decreased carbon emissions, as all vehicles can be controlled from a central control center, and the control center can choose the shortest, most efficient routes and from which source the vehicles will be deployed, depending on the aircraft’s stand location.

A similar model can be created for any other airport, on the basis of which is scheduled to verify the possibility of technical implementation of new control technologies of ground vehicles.. The practical implementation of these new technologies should be solved taking into account the requirements of ICAO and IATA, in particular ICAO Annex 14.

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A Fuzzy and a Monte Carlo Simulation Approach to Assess and Rank Transportation Vehicles

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Abstract

The technological differences among conventional, hybrid and alternative fuel vehicles and buses, the large number of variables in the sustainability assessment of transportation systems and the subjective judgment of decision makers introduce uncertainty. The objectives of this paper are to develop and present a fuzzy and a Monte Carlo Simulation (MCS) approach for the sustainability assessment of urban transportation vehicles and evaluate the applicability of the methods to selected indicators for ranking the sustainability performance of vehicles. The fuzzy method provided vehicle rankings on a continuous scale and integrate vehicle technology and fuel characteristics in the assessment, whereas the MCS generated a range of outputs in a probability distribution to represent the uncertainty associated with data collection and sustainability indicators.

Keywords: Vehicle technology; uncertainty; fuzzy methods; monte carlo.

1. Introduction

New vehicle technologies and fuel types, with no long term data and only limited short term data, introduce uncertainty in the evaluation of new transportation modes and in the formation of environmental and transportation strategies. New vehicle and fuel features, with an unexplored impact on sustainability and transportation planning, necessitate that uncertainty should be incorporated in sustainability assessments. Additionally, the complexity of transportation systems and the numerous indicators that are developed for the assessment per se invite uncertainty because required data may be incomplete. Uncertainty can be treated with probabilistic methods that require data to have a statistical basis. However, some input variables in a decision making process do not have a statistical basis, therefore other methods such as the fuzzy logic are required. Fuzzy logic methods may combine vague and uncertain criteria with well-defined and/or quantitative criteria to obtain the best alternative (Hardy 1995).

In fuzzy logic, imprecise information can be represented by linguistic values that through an inference system can provide precise conclusions. Fuzzy methods are recommended for application in sustainability oriented problems because such problems include non-uniform quantities and data, uncertain information, imprecise data and interrelations between sustainability dimensions (Pislaru and Trandabat 2012; Rossi et al. 2013). The objectives of this paper are to develop and present a fuzzy and a Monte Carlo Simulation approach for the sustainability assessment of urban transportation vehicles and evaluate the applicability of the method to selected indicators for ranking the sustainability performance of vehicles. The fuzzy method has been chosen for its ability to incorporate imprecise and vague information in decision making process. A Monte Carlo Simulation is also used in the calculation of the distribution percentiles of the sustainability indices for the five vehicle types by taking into account the uncertainty in of the input indicators. A recent study by Mitropoulos and Prevedouros (2013) developed a sustainability framework for assessing the sustainability performance of urban transportation vehicles using several powerplants and fuels under various scenarios. The study herein develops a fuzzy logic and Monte Carlo based method for incorporating uncertainty into sustainable transportation planning and uses the results from Mitropoulos and Prevedouros (2013) to test the method.

2. Sustainability Assessment Framework of Urban Vehicles

The proposed sustainability framework consists of five dimensions that are captured by the goals for governing transportation systems: Environment, Technology, Energy, Economy, and Users. The goals of the framework are to help a community meet its needs by: 1) Minimizing environmental impact and energy consumption; and 2) Maximizing its economy, user and community satisfaction, and technology performance. (Technology refers to the features of modes that support community livability, enhance public health, safety and comfort for all their users.) A set of indicators was developed for assessing the sustainability performance of five urban transportation vehicles based on the framework's five dimensions. The indicators address objectives by identifying individual vehicle features that contribute towards maximization of sustainability. When the impacts (i.e., positive or negative) of those features of sustainability are aggregated for all vehicles on the network, their value determines goal achievement and ways to move a transportation system towards sustainability. The sustainability framework was the methodological guide for developing a sustainability assessment tool.

All vehicles were assumed to use the same highway infrastructure; roads and related traffic infrastructure were not part of the assessment. The five urban vehicles examined were: Internal Combustion Engine Vehicle (ICEV), Hybrid Electric Vehicle (HEV), Electric Vehicle (EV), Diesel Bus (DB), Hybrid Diesel Electric Bus (HDEB). Vehicle specifications were necessary for estimating their impact on the five sustainability dimensions (i.e., Environment, Technology performance, Energy, Economy and Users) that capture the goals of a transportation system. For vehicle types, such as the ICEV, the HEV and the EV, the most representative vehicles were selected based on their sales volume (Edmunds 2012). Vehicle type refers to vehicle propulsion technology (e.g., internal combustion engine, electric motor or hybrid), and basic functionality (e.g., car/van, light-truck, bus, etc.) In summary, the assumption for modelling emissions and energy indicators per life cycle stage are described below.

Manufacturing. Manufacturing emissions and energy were modeled in The Greenhouse Gases, Regulated Emissions and Energy Use in Transportation GREET (CTR 1998; CTR 2005; CTR 2006) including vehicle materials, batteries, fluids and vehicle assembly. Specific input assumptions related to each vehicle and its components are extracted from the official specifications sheet of each vehicle (e.g., vehicle weight, battery weight, fluid weight, other material percentage by weight).

Fueling. GREET is used for the fuel life cycle ("well to wheel"). The model estimates the emissions and energy associated with primary energy production (feedstock recovery), transportation and storage, and with fuel production, transportation, storage and distribution. The fuel production option for conventional gasoline and low sulfur diesel is petroleum. For electricity generation the following mix is assumed: Coal 50.4%, nuclear power 20.0%, natural gas 18.3, residual oil 1.1%, biomass 0.7%, other 9.5% (i.e., hydro, solar, wind and geothermal).

Operation and Idling. For the operation stage, MOBILE6.2 (EPA 2003) was used to estimate the emissions generated from gasoline vehicles. Urban average speeds of 28 mph and 12 mph were used for passenger vehicles and buses, respectively (TCRP 2003; APTA 2009; TTI 2009). Energy consumption was estimated with GREET. Idling emissions were estimated based on the assumption that the 2.5 mph emission factors can be applied to the entire idling time (EPA 2003). EIO-LCA (Hendrickson et al. 2006) estimates the materials and energy resources required for and the environmental emissions resulting from economic activities.

Maintenance. Vehicle maintenance includes the maintenance and disposal of vehicle parts. GREET examines the emissions and energy associated with vehicle disposal. EIO-LCA was used to estimate the emissions and energy inventory associated with automotive maintenance and the tire manufacturing services based on maintenance costs. The quantification models and assumptions that produce the indicator estimates in Table 1 are detailed in Mitropoulos and Prevedouros (2013).

Table 1. Quantified vehicle sustainability indicators and relative indices for sustainability dimensions

Sustainability Dimension	Indicator	Units	ICEV	HEV	EV	DB	HDEB
Environment	CO_2 (w/ C in VOC & CO)*	*grams/ PKT*	336.16	180.20	211.89	203.81	161.56
	CH_4	*grams/ PKT*	0.47	0.29	0.34	0.21	0.18
	N_2O	*grams/ PKT*	0.01	0.01	0.01	0.00	0.00
	GHGs	*grams/ PKT*	351.07	189.52	221.21	211.27	169.01
	VOC	*grams/ PKT*	0.58	0.52	0.04	0.14	0.12
	CO	*grams/ PKT*	4.30	4.27	0.27	0.56	0.52
	NO_x	*grams/ PKT*	0.55	0.47	0.25	0.63	0.63
	PM_{10}	*grams/ PKT*	0.11	0.09	0.30	0.04	0.04
	SO_x	*grams/ PKT*	0.21	0.22	0.60	0.10	0.08
	Average noise level	*dB*	61	57	57	78	78
Technology Performance	Fuel frequency	*minutes/PKT*	0.008	0.006	0.015	NA	NA
	Maintenance frequency	*minutes/PKT*	0.012	0.011	0.006	0.002	0.002
	Space occupied	*m^2/passenger*	7.6	6.8	6.8	3	3.1
	Engine power	*kg m/kg*	0.015	0.015	0.018	0.011	0.007
Energy	Manufacturing energy	*Mjoule/ PKT*	0.385	0.393	0.443	0.208	0.243
	Fueling energy	*Mjoule/ PKT*	0.782	0.342	1.227	0.297	0.254
	Operation energy	*Mjoule/ PKT*	3.051	1.554	0.899	2.238	1.604
	Maintenance energy	*Mjoule/ PKT*	0.170	0.165	0.114	0.125	0.117
Economy **	Manufacturing cost	*$/PKT*	0.091	0.098	0.142	0.034	0.057
	Operation (user costs)	*$/PKT*	0.156	0.105	0.092	0.398	0.038
	Maintenance cost	*$/PKT*	0.028	0.026	0.016	0.027	0.026
	Any form of subsidy	*$/PKT*	0.000	0.000	0.034	0.168	0.168
	Cost for unreserved parking	*$/passenger*	188.9	188.9	0	0	0
Users	% of time not available for user's usage based on 24h	*hours of down time or not operable per year expressed as an annual %*	0.03%	0.02%	9.61%	20.83%	20.83%
	% of time not available for user's usage based on 19h	*hours of down time or not operable per year expressed as an annual %*	0.04%	0.03%	3.47%	0.00%	0.00%
	Passenger space	*m^3/passenger*	0.574	0.529	0.521	0.563	0.509
	Goods carrying (cargo) space	*m^3/passenger*	0.085	0.129	0.068	0.054	0.054
	Leg room front	*cm*	105.9	107.9	106.9	68.6	68.6
	Fuel frequency	*number of stations in operation*	121,446	121,446	626	NA	NA

Note (*): The carbon fraction in VOC and CO is considered in the total CO_2 emissions because carbon in VOC and CO will eventually be converted to CO_2 with further atmospheric chemical reactions (oxidation).

Note (**): All costs are converted in 2011$. All Economy indicators are assumed to have negative impact to sustainability. Indicators are perceived from users' point of view; therefore they reveal how vehicle monetary parameters may affect vehicle utilization and make sustainable or unsustainable a transportation vehicle for a chosen network.

3. Fuzzy Logic Method

The fuzzy methodology used herein to assess sustainability of urban vehicles is divided into four steps: a) Fuzzification, b) Inference step, c) Aggregation, and d) Defuzzification. In the fuzzy sustainability assessment, the Overall Sustainability Performance per vehicle type is composed by five primary components which represent the sustainability dimensions: environment (ENV), technology performance (TECH), energy (ENR), economy (ECON) and users (USER). Each of the primary components has inputs which are represented by the sustainability indicators. Sustainability indicators were grouped in these five sustainability dimensions. The complete fuzzy sustainability assessment method consists of Levels I and II. The output of each fuzzy method in each level is a corresponding sustainability index.

3.1. Fuzzification

At Level I, normalized input variables (i.e., sustainability indicators) are fuzzified by being transformed to linguistic values that have two fuzzy sets: "Unsustainable" (UNS) and "Sustainable" (SUS). The "UNS" is defined for normalized indicator values ranging between [0, 0.499] for which unsustainability is greater than sustainability; and the "SUS" is defined for normalized values ranging from [0.5, 1] for which sustainability is greater than unsustainability. The equivalent grade of membership for value 0.5 between unsustainable and sustainable levels reveals the uncertainty of appraising correctly the sustainability level of an indicator (Figure 1a). Similarly, primary sustainability components (i.e., ENV, TECH, ENR, ECON and USER) are defined by using linguistic values with three fuzzy sets "Low" (L), "Medium" (M) and "High" (H) as shown in Figure 1b. The Overall Sustainability Performance is defined by using three fuzzy sets: "Weak" (W), "Acceptable" (A) and "Strong" (S) as shown in Figure 1c. In this study triangular and trapezoidal membership functions $\mu(x)$ are used for simplicity. A trapezoidal fuzzy set is used to represent the range of uncertainty for the Overall Sustainability Performance (OSP). Trapezoidal functions represent an increased uncertainty in the estimation of the OSP. The extent of the overlap between the OSP values is described by the membership functions in Figure 2c.

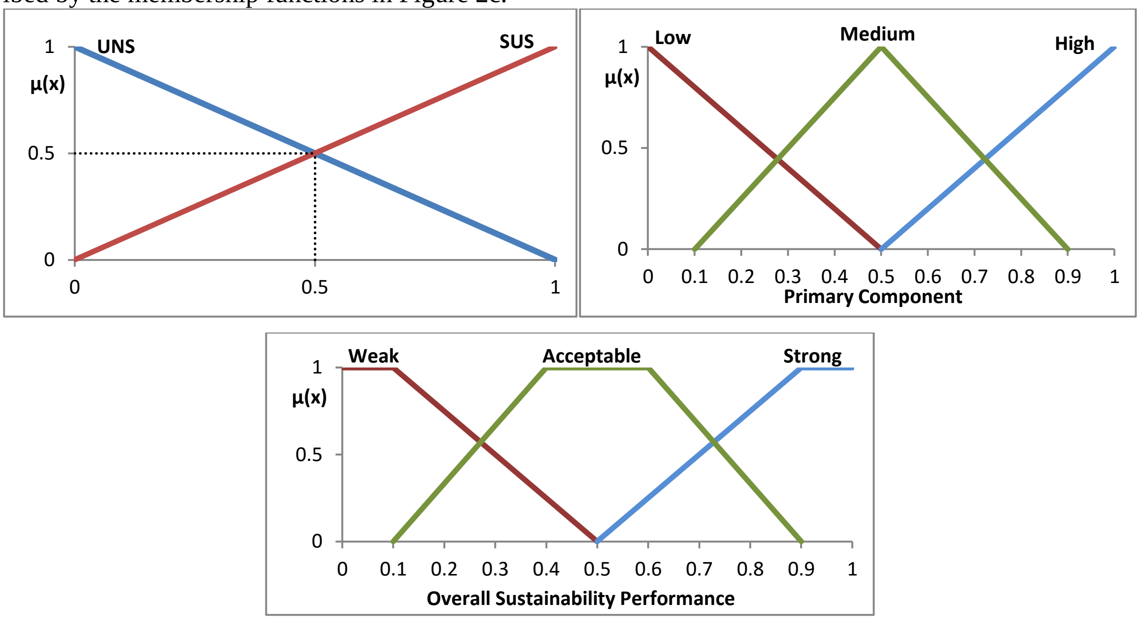

Fig. 1. Fuzzy sets and corresponding membership functions μ(x), (a) membership function for the indicator, (b) Membership function for the primary component, (c) Membership function for the overall sustainability performance

3.2. Inference Step

This study uses a fuzzy system with multiple inputs, using the same linguistic values and a single output. The inference step is applied five times for inputs of the ENV, TECH, ENR, ECON and USER components and one time for inputs of the OSP, generating five plus one sustainability scores. The rules used in each inference step express in the case of the sustainability framework the dependence of a sustainability dimension on corresponding indicators. Rules of *"If-Then*" are used to generate an output from combined input values; the outputs from Level I are used as inputs at Level II. In this study the minimum inference method (i.e., *"min, If-part"*) is used to estimate the outputs of each level. The minimum operator is expressed by the term *"and"* in the set rules. Each rule is assigned a positive weight, which measures its relative importance on the implication process. For this study all rules are assigned the weight of one.

The rule base is obtained by assigning integer values to fuzzy sets (Pislaru and Trandabat 2012; Phillis and Davis 2008). The fuzzy sets for sustainability indicators at Level I are assigned integer values of 0 and 1, where 0 is assigned to the fuzzy set “UNS” and 1 to the fuzzy set “SUS”. Similarly for primary sustainability components, the fuzzy sets are assigned integer values of 0, 1 and 2, where 0 is assigned to the fuzzy set “Low”, 1 to “Medium” and 2 to “High”. The estimated sum is assigned to a specific fuzzy set from “Low”, “Medium” and “High” for the ENV, TECH, ENR, ECON and USER components and to the fuzzy sets “Weak”, “Acceptable” and “Strong” for the Overall Sustainability Performance. Estimated sums of inputs for component and corresponding fuzzy sets are shown in equation 1:

$$ENV = \begin{cases} L, & Sum = 0,1,2 \\ M, & Sum = 3,4 \\ H, & Sum = 5,6,7 \end{cases} \quad TECH = \begin{cases} L, & Sum = 0,1 \\ M, & Sum = 2 \\ H, & Sum = 3,4 \end{cases} \quad ENR = \begin{cases} L, & Sum = 0,1 \\ M, & Sum = 2 \\ H, & Sum = 3,4 \end{cases} \quad ECON = \begin{cases} L, & Sum = 0,1, \\ M, & Sum = 2,3 \\ H, & Sum = 4,5, \end{cases}$$

$$USER = \begin{cases} L, & Sum = 0,1,2 \\ M, & Sum = 3,4 \\ H, & Sum = 5,6 \end{cases} \quad OSP = \begin{cases} W, & Sum = 0,1,2,3 \\ A, & Sum = 4,5,6 \\ S, & Sum = 7,8,9,10 \end{cases} \qquad \text{(eq.1)}$$

Similarly, all sums for each rule are estimated and assigned to fuzzy sets “Low”, “Medium” and “High” of the primary components at Level I. The number of rules per output is: ENV – 128 rules (7 input variables), TECH – 16 rules (4 inputs variables), ENR – 16 rules (4 inputs variables), ECON – 32 rules (5 inputs variables), USER – 64 rules (6 inputs variables). The final outcome at Level II is an evaluation of a vehicle’s Overall Sustainability Performance as “Weak”, “Acceptable” or “Strong”. The rule base for estimating Overall Sustainability Performance is comprised of 3^5 = 243 rules.

3.3. Aggregation

Fuzzy inputs were matched to their membership functions by using the “if-then” rules and then the outputs were aggregated. The fuzzy sets that represent the outcomes of each rule are combined into a single fuzzy set in the aggregation step. In this study the maximum aggregation method is used. Aggregation only occurs once for each output variable, just prior to the final step, defuzzification. For the outcomes of two rules represented by the produced fuzzy sets $\mu^1(x)$ and $\mu^2(x)$ the aggregated fuzzy set is represented by a membership curve (Pham and Castellani 2002):

$$\mu_i(x) = \max\left(\mu_i^1(x)\mu_i^2(x)\right) \qquad (eq.2)$$

3.4. Defuzzification

Defuzzification is the final step of the fuzzy method, in which a single crisp value is estimated. The input to the defuzzification step is a single fuzzy set produced in the aggregation step. The defuzzification technique of the center of gravity or centroid was used (equation 7). This technique takes the center of gravity of the membership function of the conclusion, which combines the membership function of each set rule. Where x^* is the defuzzified output, $\mu_i(x)$ is the aggregated membership function and x is the output variable.

$$x^* = \frac{\int \mu_i(x)\, x\, dx}{\int \mu_i(x)\; dx} \qquad (eq.3)$$

4. Sustainability Assessment Results

The fuzzy logic was applied for the sustainability assessment of five transportation vehicle types over five sustainability dimensions. The indicator values were weighted per passenger kilometer travelled (PKT). The Sustainability Index (SI) per dimension and the Overall Sustainability Performance index per vehicle type summarize the sustainability performance for the five vehicle types. Based on fuzzy logic based results, among the five vehicle types examined, the most sustainable vehicle is the hybrid bus with a score of 57.8 followed by the diesel bus with a score of 55.7. The overall sustainability performance for the EV, the HEV and the ICEV was 55.0, 51.1 and 48.2, respectively. Propulsion systems that depend exclusively or partially on electric drive did better than the traditional internal combustion engine technology when buses and passenger cars are compared separately.

The EV achieves the highest sustainability score among passenger cars due to its lower life cycle costs and environmental impact compared with the ICEV and the HEV. EV's score for Users was the lowest among passenger vehicles due to the assumption that 10% of the annual charging requirements obligate the user to stop to charge the vehicle, and due to the undeveloped network of charging stations compared to the gasoline dispensing network. Improvements in range performance and speed of charging will likely make EVs more competitive.

The EV has the highest economic sustainability index among passenger vehicles. The EV performs well for Economy due to its low maintenance and low fuel cost. Vehicle occupancy plays a critical role when estimating results on a passenger-kilometer basis; this is seen in the sustainability indices of DB and HDEB. The HDEB has the highest index for Environment with a significant difference from all other vehicles. Results for Environment show that utilization of alternative fuel technologies combined with policies that increase vehicle occupancy have the potential to improve passenger vehicle sustainability performance faster. For example, if occupancy was increased to two for all types of passenger vehicle, e.g., with extensive use of HOV-2 and HOT lanes, then the HEV would have the highest sustainability index of all vehicles, while DB would equal the ICEV's index. Emission intensity and sources differ for each vehicle type. For example, while ICEV produces more CO_2 emissions during its operation, EV produces more CO_2 during the production of its fuel. Policy formulation for treating impacts related to emissions should be based on the number and intensity of emission sources for each region. Without accounting for upstream emissions and energy requirements for alternative fuel vehicles, assessment of operation-only vehicle emissions and consumption create strong biases against ICEV, HEV and DB. Upstream emissions from, and energy requirements for vehicle fuel production, depend on the electricity mix used for every community. Therefore they are likely to vary significantly for different geographical areas.

Table 2. Sustainability assessment results and rankings per vehicle type using the fuzzy logic method

	Environment		Technology		Energy		Economy		Users		Overall	
	Ranking	**Fuzzy**	**Ranking**	**Fuzzy**	**Ranking**	**Fuzzy**	**Ranking**	**Fuzzy**	**Ranking**	**Fuzzy**	**Ranking**	**Fuzzy**
ICEV	5	45.6	5	36.9	5	34.2	5	43.7	2	29.6	5	48.2
HEV	4	54.6	3	42.2	4	48.3	4	49.5	1	40.8	4	51.1
EV	3	67.2	4	37.0	3	50.0	1	70.8	4	22.0	3	55.0
DB	2	67.6	2	65.4	2	62.5	3	50.0	3	23.6	2	55.7
HDEB	1	71.2	1	65.9	1	82.2	2	52.0	5	8.2	1	57.8

The results from the fuzzy method are not affected as much by the normalized values of 0 and 1. The set of indicators that is used for each vehicle to estimate the final score for one of the five sustainability dimensions in Table 2 does not activate all the predefined rules. Vehicle ranking changes in Table 2 tend to occur when several values of 0 or 1 exist in a set of vehicle indicators; such extreme values represent most or least sustainable performance relative to other vehicles. From a practitioner perspective, fuzzy logic indicators have the potential to be used in the assessment of transportation proposals, projects and alternative policies (e.g., parking, vehicle and fuel cost, vehicle occupancy, subsidy for alternative fuel vehicles). This method enables comparisons by mode type (e.g., private vehicle with technology X vs. bus), by broad class (e.g., motorized vs. non-motorized vehicles), by system (e.g., BRT vs. Light Rail), by corridor (e.g., HOT lanes vs. Mass Transit), and by area (comparisons of sections in the same city, or comparisons among cities or metro areas).

5. Monte Carlo Simulation

Monte Carlo Simulation (MCS) is a general procedure for risk and uncertainty analysis where random sampling is used to incorporate the inherent uncertainty or risk associated with the measurement of input variables (e.g., the measurement of the indicators for each of the sustainability dimension). MCS carries out a probabilistic analysis that treats the inputs of the sustainability index framework as ranges of values, it assigns a likelihood of occurrence to those values and allows for simultaneous variability among inputs, so that the outputs of probabilistic analysis are presented as a range with likelihood of occurrences (Bukowski and Wartenberg 1995, Chen et al. 2002).

In this research, the MCS is used in the calculation of the distribution percentiles of the sustainability indices for the five vehicle types by taking into account the uncertainty in the quantification of the indicators. The MCS is used in this research to reflect the fact that the values of the sustainability indicators per vehicle type should not be considered in a deterministic way, but instead as a range of values with a confidence interval and a probability distribution. For example, different vehicle models with similar vehicle type, which are made by various manufacturers can have slightly different measurement results and the measurements may have inherent observational errors.

In this study 5,000 iterations MCS were conducted to generate 5,000 data samples for each indicator and each vehicle type; the MCS process reached its convergent and stable status after 5,000 iterations. In practice, the sample size of MCS varies considerably for different projects or research subjects. The simulation results with nine deciles ranging from 5% to 95% show that:

- For the Environmental SI, the HDEB has slightly the highest sustainability level than other vehicle types. The EV and the DB appear to be indifferent in terms of Environmental sustainability. Still, the ICEV has the lowest environmental sustainability level.
- For the Technology SI, the HDEB and the DB have the highest sustainability level than other vehicle types and the difference in technology sustainability between the HDEB and the DB is negligible. The EV and the HEV appear to be indifferent in terms of technology sustainability. The ICEV has the lowest technology sustainability level.
- For the Energy SI, the HDEB has slightly higher sustainability level than the DB, but both are significantly higher than other vehicle types. The ICEV has the lowest energy sustainability level. The EV and the HEV appear to be indifferent in terms of Energy sustainability.
- For the Economy SI, the EV has significantly the highest sustainability level and the ICEV has significantly the lowest sustainability level compared to other vehicle types. The HDEB and the DB appear to be indifferent in terms of economy sustainability.
- For the User SI, the HEV has the highest sustainability level, followed by the ICEV. The DB and the HDEB appear to be indifferent in terms of user sustainability level; while the EV has the lowest user sustainability level.
- For the Overall SI, the HDEB is slightly more sustainable than the DB. The HEV and the EV have an insignificant difference between each other. Overall, the ICEV is the less sustainable vehicle type.

Table 3. Summary of vehicle types sustainability ranking

Sustainability Level	Environment SI	Technology SI	Energy SI	Economy SI	Users SI	Overall SI
High	HDEB	DB, HEDB	HDEB, DB	EV	HEV	HEDB
	DB, EV	HEV, EV	HEV, EV	HDEB, DB	ICEV	DB
	HEV	ICEV	ICEV	HEV	DB, HEDB	EV, HEV
Low	ICEV			ICEV	EV	ICEV

The results of the MCS on sustainability index and the rankings of all the vehicle types are summarized in Table 3. As a conclusion, the MCS added value to this study by presenting the distribution characteristics of each sustainability index for the five vehicle classes, which added a layer of conservatism and statistical confidence in interpreting and comparing the advantages and disadvantages between vehicles types.

6. Conclusion

The objective of the proposed method is to incorporate vehicle technology, fuel properties and decision making in sustainability assessment as a component of transportation planning or for the development of policies on energy, environment and transportation. The fuzzy logic method and the Monte Carlo Simulation were selected because sustainability assessment includes uncertain information, imprecise data and interrelations between sustainability dimensions. The MCS used 5,000 re-sampling iteration to integrate assumed probability distributions of the sustainability assessment framework inputs (i.e., the raw indicators) and produce the output distribution statistics of the dimensions for each vehicle type.

Vehicle types examined included light duty vehicles powered by an internal combustion engine, a hybrid electric power plant, an electric drive, as well as two heavy duty transit vehicles, a diesel bus and a hybrid diesel electric bus. The sustainability assessment method can readily accommodate electric buses, CNG/LNG-powered vehicles and motorcycles. Based on the fuzzy logic method presented herein, the most sustainable vehicle is the hybrid diesel electric bus. The electric car was found to have the best sustainability performance among light duty vehicles. Propulsion systems that depend exclusively or partially on electric drive did better than the traditional internal combustion engine technology when bus and passenger cars are compared separately.

The fuzzy logic method was found to be flexible to use qualitative or linguistic values and generate sustainability indices for sustainability assessment. The MCS incorporates in the vehicle ranking a flexible and dynamic analysis framework due to its ability to use more sophisticated distribution assumptions than the fuzzy method representing reality in a more effective way. The methods that were used for vehicle ranking in this study provide robust results for sustainable transportation planning. Sustainability assessment results by using the fuzzy and MCS were suitable tools for assessing sustainability in transportation planning by integrating vehicle technology and fuel characteristics in the assessment.

The fuzzy logic method enables the utilization of qualitative indicators or indicators that are difficult to quantify in the sustainability assessment. The proposed sustainability assessment method with fuzzified key inputs and enhances the traditional transportation planning process in three directions by including: (i) Vague and uncertain values of features of new vehicle technologies and fuels; (ii) Fuzzy interrelations between sustainability dimensions; and, (iii) Uncertainty due to the subjective judgment and preferences of decision makers.

The results are both technology and policy sensitive, thus useful for both short and long term planning. The fuzzy method supplemented by the MCS provide a comprehensive approach to enhance engineering judgment, transportation evaluations and decision making in the face of uncertainty.

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Analysis of impacts of the Rail Baltica project: cargo multimodal hubs development

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Abstract

The development of the Rail Baltica project is significant in light of implementing the EU Strategy for Baltic Sea Region and in case of a successful project implementation high quality rail connection between the Baltic States and the biggest economic, administrative and culture centers of Western Europe will be ensured. The main objective of this project is to establish a more solid link with the European central areas thus contributing to mutually beneficial cooperation. Research goal is the analysis of project impact on cargo flows in Baltic Sea Region and possibility of hub formation at the intersection of two types of railways – "eastern" and "western". In order to perform a comprehensive current situation analysis and future development assessment for the Rail Baltica project at first the list of stakeholders was recognized. A review and analysis of official forecasts about possible increase of cargo flows, including transit, is considered. Nuanced discussion has been raised about types of shipments in transit, expected cargo turnover and forecast about types of shipments imported or exported from Latvia or handled by Latvian logistics operators. On the basis of such analysis authors consider the locations, where multimodal cargo hub in Latvia could be implemented.

Keywords: Rail Baltica; cargo flows, multimodal hub; project impacts; location problem.

1. **Introduction**

In accordance of National Transportation Development Guidelines 2014-2020 one of the main directions of Latvian transport system development supporting a multimodal Single European Transport Area by investing in TEN-T. In this context the Rail Baltica project is the largest strategic project in Baltic countries that will change all

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aspects of transport business in Latvia. In transit services each 10 million tons give at least 1% GDP. Therefore, it is within the interests of Latvia to recover the lost amounts of freights and to attract new ones.

Major challenges in Baltic Sea region (BSR) countries are still poor infrastructure quality; greenhouse gas emissions; dependence on freight transit from East and oil dependency. The development of the Rail Baltica project is significant in light of implementing the EU Strategy for the BSR and in case of a successful project implementation high quality rail connection between Baltic States and biggest economic, administrative and culture centers of Western Europe will be ensured. Railway development is among the most significant prerequisites for the creation of a sustainable transportation system. Low electrification rate and high wear and tear of the existing railway network system increases the price of transportation and causes negative environmental impact.

According to Riga and Pieriga Mobility Plan and Riga City Sustainable Development strategy until 2030, the creation of an integrated transportation system and freeing of the central part of the city from transit traffic is especially important in the transport infrastructure of Riga. Promotion of polycentric development means, along with the development of Riga, promotion of the development of international, national and regional development centres defined in the strategy of Latvia 2030 as drivers of regional growth by increasing the institutional capacity of infrastructure, human resources, regions and municipalities, as well as ensuring an attractive, qualitative and creative environment for population and investors. Research goal is the analysis of the project impact on cargo flows in BSR and possibility of hub formation at the intersection of “eastern” and “western” railways.

Development of sustainable transport interchanges is a complex process involving land use planning, institutional, organizational aspects, risk assessment, economic and life cycle analysis. Freight transport interchanges are geographically determined areas, managed by one public or private body, and where all activities including transport, handling and distribution of cargo are operated by several enterprises, i.e. transport and logistics providers or users, established in the interchanges (Gogas & Nathanail, 2014). Several approaches for the definition of the types of freight terminals/interchanges/hubs based on the geographical coverage, volume and capacity are met in literature. Wiegmans et al. (1998) identified five characteristic types of terminals (Wiegmans et al., 1998): mainport, international European, national, regional and local terminal. Rodrigue and Hatch (2009) identified three types of intermodal terminals: port, rail terminals and Distribution centers. The project REFORM identified four categories of transport and logistics terminals: city terminal, freight village, Industrial and Logistic Park, Special logistic area (Nathanail, 2007). City terminals are usually located in or in close vicinities to the cities. These terminals are typically operated by forwarders and retailers.

In (Fehrl, 2013) review of relevant good practices showed that the spatial and network dimensions regard the linkages between transport infrastructure and land-use requires an adequate institutional and implementation approach in order to become effective integrative planning. The framework for decision-making sets out the factors influencing the transport development in the order of their priority shown on Figure 1 (Kabashkin, 2016). The development of higher levels is feasible when lower levels are achieved. A favorable regulatory system shall be in place before the development of infrastructure and use of technologies. The role of public authorities should be oriented to the creation and guaranteeing of equal competitive conditions for all transport network participants, usually acting on the basis of private ownership and initiative (Bazaras et al, 2013).

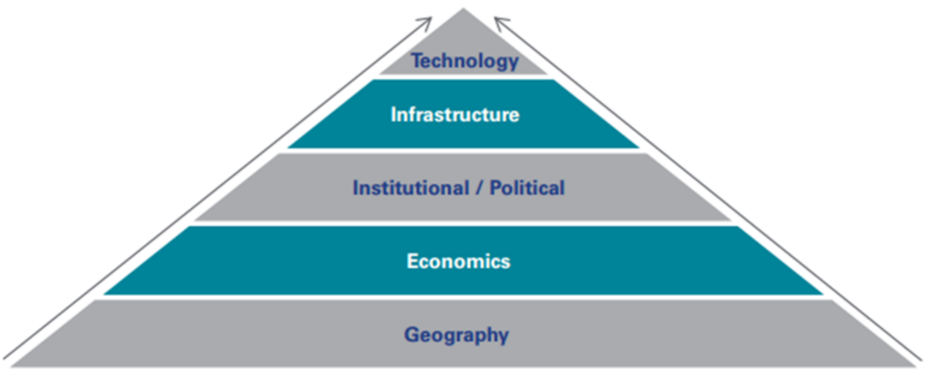

Fig. 1. Framework for transportation development (Kabashkin, 2016)

Understanding and clarifying the impacts of this project on Latvian logistic and transport sphere and possibility of hub formation at the intersection of two types of railways – “eastern” and “western” is the goal of research. In order to perform a comprehensive current situation analysis and future development assessment for the Rail Baltica project firstly list of stakeholders was recognized, than discuss the possible impacts and further development cargo hub as part of the project.

2. Project Rail Baltica highlights and main stakeholders

Rail Baltica is a rail transport project with a goal to integrate Baltic States in European rail network. The project includes Poland, Lithuania, Latvia, Estonia and indirectly also Finland since the connection Tallinn-Helsinki with the project is being prolonged (see Fig.2).

Fig. 2. Map of Rail Baltica route (Source: www.telekonta.lt).

Rail Baltica main target is reconnection of Baltic States railway network and Western Europe. Railway will establish connection between Tallinn, Riga and Kaunas by new higher speed 1435 mm UIC gauge direct line. Also new routes will connect Vilnius, Warsaw and Berlin. Construction activities planned to be started at 2020. In 2025 railway should connect Riga, Tallinn and Kaunas, and by 2030 should reach Warsaw. Latvian railway district should be 265 km long. Maximal passenger train speed – 240 km/h (average speed 170 km/h). Planned travelling time from Tallinn to Polish - Lithuanian border will be just 4,5 hours. Maximal speed for cargo trains will be limited by 120 km/h and way time for pan-Baltic route will reach 10,4 hours.

Feasibility study, made by British company AECOM in 2011 says, project investments will be 3,68 billion EUR. Latvian part of the project require 1,27 billion EUR. 85% of the project costs will be covered by European Funds.

When discussing the benefits of the project, it is pointed out that the Baltic railway infrastructure will be connected to the European railway corridor (TEN-T program). In case of a successful project implementation, in 15 years of time, high quality rail connection between the Baltic States and the biggest economic, administrative and culture centers of Western Europe will be ensured. Opportunities for a new cargo way (Nordic – Southern) as well as the development of logistics services are expected. The tourism, regions and new working places will be developed and the national safety of Latvia will be increased. It has been estimated that at least 1.5 billion euros will flow into the economy of Latvia (Sam.gov.lv, 2016a). In Tables 1 and 2are shown the statistics of Nordic – Southern corridor, provided by Ministry of Transport of Latvia.

Table 1. Demand 2008 on North-South Corridors

Demand	Road	Rail	Sea	**Total**
Bulk, ‘000 t (%)	9,835 (48%)	2,269 (11%)	8,494 (41%)	20,599
Non-Bulk, ‘000 t (%)	7,013 (46%)	587 (4%)	7,647 (50%)	15,247

Table 2. Most common cargo types by route

Most common cargo types by route	Type	‘000 t
Finland - Germany	Paper	2,549
	Wood	1,094
	Minerals	347
Finland - Poland	Minerals	1,149
	Paper	404
Lithuania - Latvia	Minerals	825
Lithuania - Estonia	Minerals	599
Lithuania - Finland	Wood	411
Latvia - Finland	Wood	1,257
Latvia - Germany	Wood	325
Poland - Lithuania	Foods	305
Germany - Finland	Metals	404

Sustainable business and organizational models are sought for collaborative schemes amongst the stakeholders of the intermodal transportation chain.

On the coasts, more and efficient entry points into European markets are needed, avoiding unnecessary traffic crossing Europe. Seaports have a major role as logistics centres and require efficient hinterland connections. Their development is vital to handle increased volumes of freight both by short sea shipping within the EU and with the rest of the world (Ec.europa.eu, 2016).

With this, most important stakeholder in Latvia should be Freeport of Riga. In terms of distance, routes through Riga are the shortest providing the possibility of transport cost reduction on rail and road from the Eastern Baltic Sea coast to the biggest cities of the Russian Federation, Belarus, Ukraine and other countries that are important and growing consumer markets. Riga is integrated into the uniform transport network of the EU, making Riga one of the most advantageous and efficient hub ports in regards to freight transshipment in Baltic Sea region.

The Port is directly connected to development of the TEN-T2 Nordic Axis and Motorways of Sea as it operates as a transport hub providing multi-modality in cargo transportation chains with the aim to ensure efficient use of resources in sustainable perspective. In the framework of the Motorways of the Sea the link to the Motorways of Baltic Sea is extremely important for the port – both to the main South-northern axis, from which the subordinate motorways of sea derive to the western and eastern shores of Baltic Sea and to its Eastern branch to the Gulf of Finland. The A category ports included into TEN-T network (including Riga) create land transport and sea motorways connection hubs. The aim of the Pan European transport corridor network is to ensure link between the TEN-T transport network and the Eastern European transport system, two of the ten defined transport corridors of the said network can be directly related to Latvia. The 1st corridor Via Baltica (via Hanseatica) intersects Latvia, and the connection with the 9th Corridor in the western-eastern direction is extremely important for Latvia.

Notwithstanding it is not officially objective of the Rail Baltica project, Freeport of Riga is still most reliable and sustainable source of benefits for the Latvian economy. New railway connection to the Freeport should open a lot of new possibilities for local companies – exporters, logistic operators, outsourcers and other businesses. While global economic and political crisis not passed in complete, Freeport of Riga still demonstrates stability (See Fig.3).

Riga is a multifunctional port and all types of cargo except for crude oil can be handled at the port. Cargo structure has considerably changed during the reviewed period (Freeport of Riga, 2009). In 2015 bulk cargo had a share of 58,03%, general cargo share of 15,46% and liquid bulk a share of 26,51% from overall cargo turnover in the port. Currently the main cargo types of the port are coal (36,27%), fertilizers (6,45%), timber (4,64%), oil products (26,31%) and containerized cargo (9,55%). Dynamics of certain cargo types have varied a lot during the reviewed period, mainly influenced by changes in relation to cargo origin, consumption markets and development trends. Due to increase of Russian coal export the volume of coal at the Port of Riga has grown considerably. Fluctuations in the wood materials market have reduced wood product volumes in the port significantly since 2008. At the same time, the share of containerized cargo on total cargo volume has continuously increased following a global trend. Infrastructure of Freeport of Riga makes this geographical point one of the most competitive points in the region of Eastern Baltic.

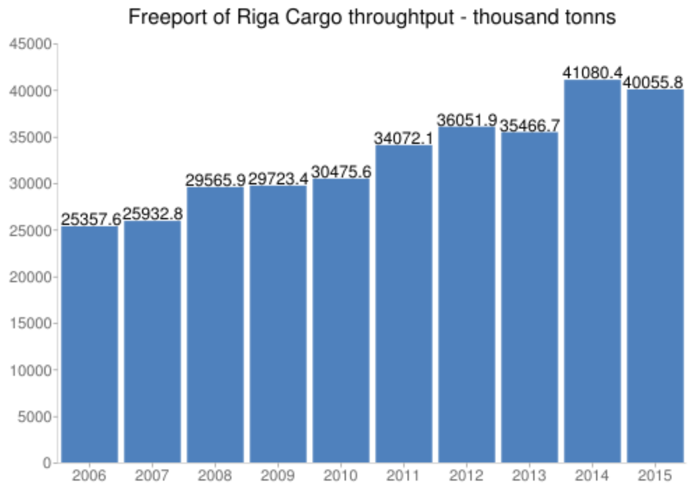

Fig. 3. Freeport of Riga turnover. Trends (Source: www.rop.lv)

Faced with the increasing constraints of financing transport infrastructure, many countries are keen to allocate their resources in a way that increases their net return to society. To facilitate such allocation, all of the wide-ranging impacts of investment in transport infrastructure should be fully understood.

It is extremely difficult to measure the exact relationship between transport infrastructure investment and regional development. Although some theoretical analyses indicate the presence of significant impacts, these studies need to be complemented by empirical evidence from existing ex-post evaluation studies (OECD, 2002).

The effects of a transportation project can be represented by a set of variables known as impact indicators or measures of effectiveness. Here is most known classification of transport infrastructure project impacts (see Table 3). The nature and severity of these impacts depend on the visibility of the transportation facility. Some impact indicators are quantitative variables such as travel time or CO emissions; others are qualitative.

Table 3. Impact classification and effects (adapted by authors from (Ko, 1996)

Class of impact	Type of impact	Changes
Direct	Travel time	Faster deliveries
	Vehicle operating costs	Reduced transport maintenance costs, optimized supply chain management
	Safety	Sustainable and safe transportation
Socio-economic	Accessibility	Increasing size of the market, more export, cheaper import
	Employment	Construction, operation and maintenance of infrastructure, expanding business
	Efficiency	New business opportunities, more competition, raise of productivity
	Social inclusion	Economic growth in degraded regions
	Environment	Less pollution and noise, safe environment

3. Spatial planning of multimodal hubs (city-hubs)

There are a lot of studies dedicated to spatial locations of logistics terminals. Many methodologies have been utilized to solve the facility location problem. Classical plant location problems were discussed in the beginning of 20th Century, however first reliable models were implemented just with arrival of computers. The location problem for minimum total delivery cost with nonlinear programming had solved by Baumol and Wolfe (1958). Some researchers (Wesolowsky, 1977; Rosenthal et al., 1978 etc.) incorporated in the model stochastic functions to account for demand and/or supply. Other approaches that have been developed include dynamic programming (Geoffrion, 1978; Tansel et al, 1989; Saaty, 1996 etc.), heuristic and search procedures (Kuehn and Hamburger, 1963). But in many location problems, cost minimization may not be the most important factor. The use of multiple criteria has been thoroughly discussed in the literature (Schniederjans and Garvin, 1997). Researchers have suggested numerous criteria for the facility location problem. These decision factors include availability of transportation facilities, cost of transportation, availability of labor, cost of living, availability and nearness to raw materials, proximity to markets, size of markets, attainment of favorable competitive position, anticipated growth of markets, income and population trends, cost and availability of industrial lands, proximity to other industries, cost and availability of utilities, government attitudes, tax structure, community related factors, environmental considerations, assessment of risk and return on assets (Ko, 1996). Qualitative factors are crucial but often cumbersome and usually treated as part of management's responsibility in analyzing results rather than quantified and included in a model formulation of the facility location problem (Lee et.al, 1981). Qualitative decision factors can be readily incorporated into facility location problem (Ko, 1996).

By author opinion most of criteria, involved in determination of perfect facility location could be implemented same way for city-hub siting. The aim of further study is application of methodologies, used for facility location problem to spatial planning of city-hub. The added value of an intermodal freight hub depends on four major factors, namely: location, efficiency, financial sustainability and rail level of service (price, punctuality, reliability or transit time). Among these, location of hubs is one of the most crucial success factors. It needs to be considered carefully as it has direct and indirect impacts on different stakeholders including investors, policy makers, infrastructure providers, hub operators, hub users, and the community (Sirikijpanichkul et al., 2007).

As example of comparison, integration decision model for distribution facility location (Ko, 1996) has been taken into consideration (see Table 4).

Table 4. Groups of location decision factors

Criterion groups	Decision factors for facility location	Decision factors for city-hub location
Population status	Population density (size)	Population density (size)
	Income trends	Income trends
Transportation conditions	Attainment of Favorable position	Attainment of Favorable position
	Number of Public transportation	Number of Public Transportation
	Walking Accessibility	n/a
	Traffic network	Traffic network
	Degree of traffic congestion	Degree of traffic congestion
	Availability of Public Transportation	Availability of Public Transportation
Market environments	Number of shops	n/a
	Number of Competitors	Number of Competitors (other hubs)
	Proximity to other markets	Proximity to other markets
Location properties	Size of Facilities	Size of Facilities
	Visibility of sites	n/a
	Parking space	Parking space
	Nearness to car parking	n/a
	Convenience to access	Convenience to access
Cost-related factors	Cost of lands	Cost of lands
	Tax structure	Tax structure
	Cost of maintenance and utilities	Cost of maintenance and utilities
	Legal considerations	Legal considerations

As shown in Table 4, most of decision factors play same important role for siting regional level multimodal hub. A new freight hub has to be economically viable so a certain transport volume has to be reached with a good price for transport and handling to ensure the new intermodal freight hub is a beneficial investment. Some of mentioned factors has paramount importance for city-hub location, which is different from facility location. Area for siting should be placed on crossroads of important cargo routes. Local stakeholders should have a perspective of expansion and be able to use new routes. Governmental policy should be directed for long-term development of business environment. Importance of every factor should be evaluated. When evaluation is done, total score should be assigned to every potential site. Then evaluation based methodologies of calculation might be implemented in order to determine best location.

One more approach, solving spatial location problem for multimodal hubs should be implemented for best results. Heuristic algorithm that combines aspects derived from both classical simple plant location problems and shortest path algorithms on multimodal networks. The proposed approach looks for the best possible modal change nodes and computes minimum cost origin-destination (further o-d) routes in the given urban multimodal transportation network using such nodes for the o-d pair under consideration. Example of implementation has been given by Ambrosino and Sciomachen (2012) in hub identification in the freight multimodal network of the city of Genoa. The application of the presented method to the multimodal logistic network model of the Republic of Latvia has allowed us to reduce the number of candidate nodes for being city-hubs to 4.

Here is most probable keypoints in Latvia, which satisfy location and transportation requirements, affected by the Rail Baltica Project:

- Iecava - village on the via Baltica highway in Iecava municipality, in the Zemgale region of southern Latvia. The village has a population of around 9 500. Village has direct access to railroad, connecting Eastern boarder railway corridor to Liepaja Sea port. Iecava has to be considered as regional multimodal hub.
- Bauska - town in Bauska municipality, in the Zemgale region of southern Latvia. Bauska is located 66 km from the Latvian capital Riga and 20 km from the Lithuanian border on the busy European route E67. At the moment Bauska has not direct access to railway track.
- Salacgriva – small seaport in the northern part of Vidzeme region, Latvia. The distance from Salacgriva to the capital of Latvia - Riga is 103 km. Export of timber, wood-working industry, food production and trade are the most important factors in the economy of town. Might be considered as multimodal hub.
- Salaspils town – satellite of Riga, the administrative center of Salaspils municipality. The town is situated on the northern bank of the Daugava River 18 kilometers to the south-east of the city of Riga and officially considered as multimodal hub on Rail Baltica route.

However, considerations about available space, charge, demand, proximity to specific infrastructures as well as the citizen’s propensity are relevant decisional parameters that have to be considered in the final choice.

4. Conclusions

This paper has conducted the decision problem of multimodal terminal spatial planning. As far as siting of city-hubs is always based on government and business close partnership, paper creating a circle of recommendations for further planning research. It also reviews and develops the concept of sustainable transportation, presents a decision-support framework that encourages the creation of transportation programs that support sustainable development, and presents a set of sustainable transportation indicators. By exploring the interconnections between the transportation system and the economy, a broader perspective is introduced that considers the transportation system through the lens of sustainable development. The authors conclude that it is important and necessary to consider the development of transportation policies and programs from sustainable transportation perspective.

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Broadcast transponders for low flying unmanned aerial vehicles

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Abstract

Present day unmanned aerial vehicle (UAV) technology in urban mobility applications is severely limited in use due to lack of reliable collision avoidance mechanisms. There are numerous applications for UAVs in urban environments, including information awareness, urban management, on-demand goods deliveries, and even parking assist, but present day legal regulations preclude their use over safety concerns, requiring presence of a pilot and restricting UAV use in urban areas.

Indeed, possibility of midair collision is a significant concern in a densely populated urban area, and will only get worse as UAV use becomes widespread.

Collision avoidance cannot be done effectively using onboard sensors. A transponder system like automatic dependent surveillance-broadcast (ADS-B) could be used to augment airspace awareness of UAVs, greatly reducing collision risks.

SPH Engineering has successfully integrated such transponders with two of the most popular consumer class autopilots. In each case a device by Sagetech was used, the smallest commercially available transponder to date. This is a major step towards commercial UAV integration into regulated airspace.

Unfortunately, ADS-B is ill suited for small low flying UAVs that are navigating unregulated airspace. While weight and power are the more obvious limitations, the use of ADS-B also requires International Civil Aviation Organization (ICAO) certification, which is both expensive and lengthy.

Furthermore, at close range receiver was overwhelmed by transmit power. In a collision avoidance scenario for delivery drones short range is exactly where reliable reception is most needed.

This article presents an approach, which is used to design a collision avoidance system in accordance with safety regulations of manned aviation that would be specific to small, commercial UAVs operating in unregulated airspace.

Keywords: UAV; collision avoidance, cooperative, infrastructure-independent

1. Introduction

Present day technology makes mass production of remotely piloted aircraft, commonly known as "drones", both feasible and affordable. UAVs can be used to improve urban mobility as part of “smart cities” (Jensen, 2016), providing mobile, real time surveillance for better city management, or be directly involved in a “here and now” application, such as parking assist (Siemens, 2015) or a mobile WiFi hotspot.

There are also attempts to use such craft for cargo deliveries. Especially, for rapid deliveries of small items to people’s homes, such as mail service and internet shopping, like Amzon’s “Prime Air”. Google’s “Project Wing” could even be used, among other things, for quick, on-demand delivery of medical supplies, directly to the patient at a press of a button – greatly improving accessibility of services while saving on transportation costs, time and lessening street traffic.

There are, of course, numerous other applications for UAVs in urban areas, which include building and infrastructure inspection, firefighting and rescue operations, 3D reconstruction and photo shoots for real estate presentations, even gas leak detection and atmosphere quality analysis using various sensors. Not only can UAVs be deployed faster than manned aircraft, they are also considerably cheaper to operate and much more environment-friendly.

Nomenclature

ADS-B	automatic dependent surveillance-broadcast
COTS	commercial off the shelf
EU	European Union
FAA	Federal Aviation Administration
ICAO	International Civil Aviation Organization
RF	radio frequency
RPAS	remotely piloted aircraft systems
TCAS	traffic collision avoidance system
UAV	unmanned aerial vehicle
USA	United States of America

At the same time there is still no exhaustive legislation dealing with the status of said systems. For example, EU law does not acknowledge even the possibility of a completely unmanned system, since the term chosen for “drones” in European law is RPAS (European Commission, 2015), not UAV, thus implying presence of a pilot. There are also strict requirements that RPAS operate within direct sight of their pilot. Interesting to note that beyond visual line of sight operations are present in the classification, but not currently permitted.

USA, on the other hand, has a blanket law that classifies any flying object that can be remotely operated as an "aircraft", which also requires compliance with FAA regulations. FAA, however, has banned all commercial use of UAVs (while providing a strict set of regulations for non-commercial use), and is issuing exemptions for commercial use (as of April 2016, this can be done electronically). Either way, both EU and USA do not recognize legally the possibility of such aircraft to be flown completely pilotless (at least, by civilian operators).

There is a technical reason for such a harsh restriction - presently such UAVs do not present the same level of safety that manned aviation enjoys. Manned aviation has specific requirements listed for each type of system, including electronic and software components (Won Keun Youn et al, 2015). Far from it, there is no way to measure safety and reliability of small commercial UAVs, since they weren’t manufactured with these requirements in mind.

As can be seen in Figure 1, UAVs can be operating below regulated airspace, and, in this case, they do not present any danged to aircraft. They do, however, remain dangerous to everything below. A UAV may range in weight from below 1 kg. and up to several (sometimes - dozen) kg. If it falls down, it may injure people or damage property. Such an event may occur due to mechanical or electric failure, as well as software failure. These three, however, are outside the scope of this paper – higher manufacturing standards could satisfy the former requirements.

Another two possibilities are midair collision and collision with a static object (UAVs could be restricted to fly high enough not to run into people). Avoiding stationary objects is a problem for advanced route planning which should include 3D environment maps.

Midair collisions between small UAVs, however, present a challenge – due to their relatively small size, such craft are impractical to detect with onboard sensors. At the same time, the "layer" of unregulated airspace is somewhat thin, and with future proliferation of UAVs could become highly saturated, making such collisions likely.

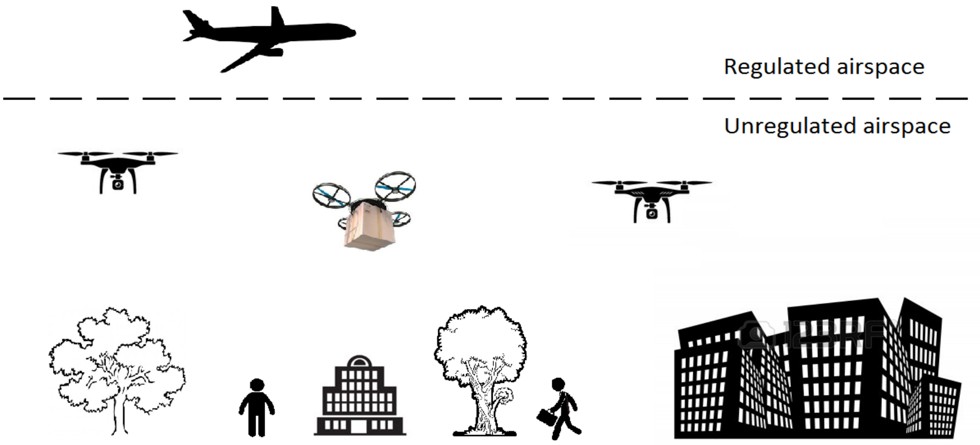

Fig. 1. Operating environment.

A thorough review of presently available collision avoidance technologies was performed by the author (Lancovs, 2015), and the conclusion was that a cooperative, infrastructure-independent solution is required. It is also the only approach that can provide a specific chance of failure regardless of sizes of UAVs involved in a collision avoidance scenario, since it doesn't rely on physical attributes of craft. Given the possibility of human injury or death, this collision avoidance system can be classified as a "Level A system" with a possibility of catastrophic outcome, thus requiring chance of failure $P < 10^{-9}$ (Won Keun Youn et al, 2015). This paper focuses on establishing the approach to designing such system, which allows maintaining required level of P throughout all the potential collision avoidance scenarios (depending on type of aircraft, speeds, courses and other variables).

2. The approach

A good example of a cooperative, infrastructure-independent system is ADS-B. It is used in manned aviation for the same purpose of collision avoidance. ADS-B consists of a transmitter and a receiver (the former is commonly called "transponder" for historic reasons – previous system worked on a "ping-respond" principle). ADS-B transmits information about aircraft type, position, heading and speed.

Each aircraft has a specific cylindrical area around it, and, should any other aircraft enter this safety zone, a collision warning will be produced. A Kalman filter is most often used to determine potential collisions based on aircraft courses before they actually enter this safety zone. For example, both TCAS and ADS-B rely on such filters, and there is a proposition to use both simultaneously (Yajun Xu, 2013). A specific set of rules is used to determine how to respond in case of a potential collision. Both systems only inform the pilot, they do not take over control.

At least two integration projects with such transponders were completed successfully (SPH Engineering, 2015, 2016), and, with proper ICAO certification, vehicles carrying these transponders are legally permitted in regulated airspace. Devices used were the smallest available transponders at the date of experiment (Sagetech, 2016).

Unfortunately, there are limitations to the widespread use of ADS-B on UAVs. These transponders require a significant amount of power to operate, and their signal strength requires placing the antenna away from onboard electronics (which are normally not shielded). Another problem encountered was lack of reliable close range reception: receivers designed to catch signals from sources hundreds of kilometers away become overwhelmed.

For small UAVs flying in unregulated space there is no need to be visible by manned aircraft, nor there is any to be seen at extreme ranges. However, reliable reception of signal should happen at ranges as close as it is still possible to avoid a collision physically. In other words, ADS-B works and is useful for UAVs that are to fly in regulated airspace, but it wasn't designed for this particular scenario. Also, it is far too expensive, often in excess of the value of UAVs that would carry it.

Yet the principle is sound, and can be applied to UAVs. However, a collision avoidance system for such UAVs needs to work at specific ranges and be reasonably affordable. The latter can be achieved by relying on COTS components. Figure 2 shows the elements of a cooperative infrastructure-independent collision avoidance system, similar to ADS-B.

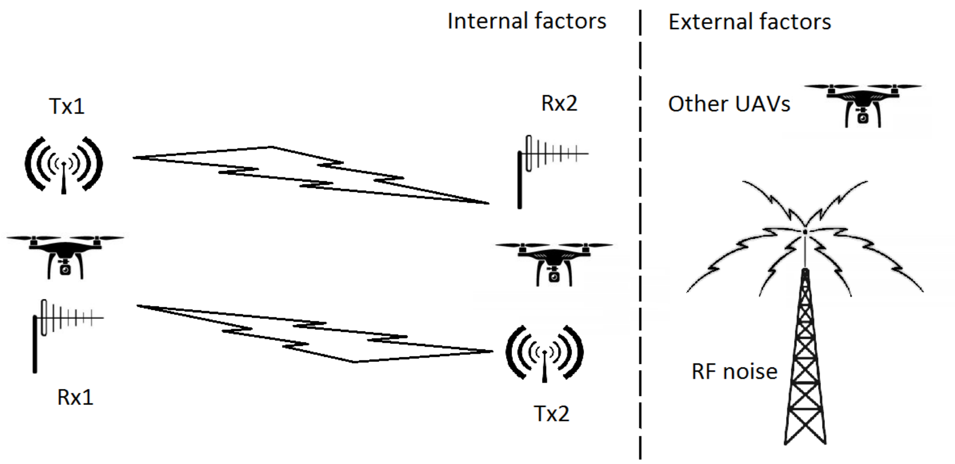

Fig. 2. Cooperative, infrastructure-independent collision avoidance system

Much like ADS-B, UAVs transmit information about their location, speed and heading, but also type and capabilities. This information is received by other UAVs, and an informed decision for collision avoidance can be made. A key requirement to designing such system is to maintain probability of failure P within specification. It is influenced by both internal system factors X and external ones Y. It must be maintained at a range of distances from the shortest d_{min} to the longest d_{max}, at which collision avoidance is required. Distances are dependent on physical capabilities of craft and denote best and worst case distances, at which it is still possible to avoid a collision.

Internal factors include transmitter and receiver parameters, signal encoding type and frequency, transmit power and message frequency, while external factors are physical capabilities of UAVs, transmissions by other UAVs saturating the channel, as well as any RF noise from other sources (expression 1). Therefore, it is important to maintain P, given Y, by finding appropriate X (expression 2).

$$P = f(X, Y, d); \tag{1}$$

$$P(X, Y, d) < 10^{-9} \tag{2}$$

Since X depend on Y, d_{min} and d_{max}, it is important to identify d_{min} and d_{max} first. However, d_{min} and d_{max} is itself dependent on X, as it includes the distance flown by both aircraft while information is being received. Naturally, different aircraft may travel a different distance during that time, hence d_{min} and d_{max} instead of just a single distance. A model needs to be created to simulate different encounter scenarios, with the purpose of identifying X, by iteratively adding more and more external factors Y, with d_{min} and d_{max} being an intermediate result. Table 1 shows iterative modeling approach.

Table 1. Modeling iterations and added factors

Iteration	Factors added	Purpose
1	UAV capabilities	Establish initial d_{min} and d^{max}
2	Radio channel parameters	Include reception reliability into the model
3	Transmissions by other aircraft	Examine potential saturation of RF channel
4	EM noise	Identify influence of real, noisy environment on the system
5	Additional UAVs	Examine system behaviour if more than two UAVs are avoiding a collision

As noted above, there are five iterations. The beginning one deals with establishing baseline requirements for the system, such as minimum and maximum range of reliable reception. At this stage it is assumed that the channel is ideal, loss-free, noise-free, and with unlimited bandwidth, meaning, if there is a possibility to physically avoid collision, had both (or one) craft been aware at the time, they would be attempting to avoid. This stage has no uncertainty, since physical parameters of aircraft are certain, therefore minimum distance when it is still possible is also.

Second iteration introduces ratio channel parameters. Bandwidth, losses, transmit delay and encoding are considered. Before this can be done, however, a set of hardware solutions must be chosen based on requirements from the previous iteration. Once that is done, an inverse problem of achieving a specific reliability is calculated for each possible configuration. Reliability in this case is defined as a probability of successfully resolving a potential collision.

Third iteration introduces additional aircraft as “speakers” on the same channel. This particular iteration is meant to examine effects of ether saturation on collision avoidance. It is also grounds for establishing upper border for transmit power – having too much range in this case means having more transmitters using bandwidth, potentially impairing ability to rebroadcast.

Fourth iteration adds environmental EM background with additional signals coming from non-related sources. Depending on a specific hardware solution, different transmission wavelength and receiver sensitivity, we may see different results, and solutions with better theoretical reliability may fall short due to heavier use of the same (or nearby) frequency for other purposes. This and the following iterations are not intended within the scope of original research plan, and may be performed at a later time.

Fifth and final iteration attempts to solve a problem of multiple aircraft avoiding a collision. Note that with manned aircraft, due to echeloned approach and regulated airspace, such scenarios are considered very unlikely. For UAVs in unregulated space such probability must be, at the very least, examined, since there is no echeloned approach, and whatever system is to provide collision avoidance, it is likely to be solely responsible for safety.

What we are not dealing with in any iteration is physical failure of aircraft. That is beyond the scope of this research, and, in the event of such failure, cooperative collision avoidance mechanism will have little effect on the outcome.

3. Experiments

Experiments are performed at each iteration of the model, and cover all potential encounter scenarios. Re-testing is necessary to ensure P remains within limits, as new factors are introduced. If P exceeds allowed limits, model parameters X are adjusted to bring P back into permitted range. Table 2 shows encounter scenarios being modeled.

Table 2. Experiment plan – encounter scenarios.

Aircraft state	Course	Description
Both aircraft moving, both responding	Head on	Aircraft incoming straight at each other at maximum speed
	Intersect	Aircraft on intersecting course with such timing that a collision is possible
	Chase	Faster aircraft following a slower one on the same course
	Climb / descend	Same as intersect, but vertical speeds used

Both aircraft moving, only one responding	Head on	Aircraft incoming straight at each other at maximum speed
	Intersect	Aircraft on intersecting course with such timing that a collision is possible
	Chase	Faster aircraft following a slower one on the same course
	Climb / descend	Same as intersect, but vertical speeds used
One aircraft stationary and not responding	Head on	Aircraft incoming straight at each other at maximum speed
	Climb	Descending towards a stationary craft
	Descent	Climbing towards a stationary craft

Experiments produce different minimal safe encounter distances, i.e., distances, at which an encounter does not end in a crash. Minimal and maximal values for these are used as d in the next iteration. Final iteration produces a set of X that is guaranteed to provide failure probability $P < 10^{-9}$. These can then be used as requirements for a physical implementation of a cooperative, infrastructure-independent collision avoidance system.

4. Conclusion

Due to the current state of legislation in the field of unmanned aviation, exact requirements may change, but the actual threats, such as midair collisions, will remain the same, and should be taken into account in any scenario where potential exists for multiple UAVs sharing the same airspace. The approach proposed in this article can be used to produce a collision avoidance system for UAVs, enabling them to operate in a densely populated area while providing a specific level of safety, as required by current (and future) aviation norms and regulations.

In order for this approach to succeed, a wide variety of factors needs to be taken into account at every stage of modeling, with each step bringing the model closer to the actual operating environment. Additional factors and iterations can be added, should new requirements arise due to either changes in operating environment, or relevant legislation.

There are three directions to pursue further. The first one is performing iterative modeling process with the purpose of obtaining technical specification for the actual collision avoidance system, while maintaining a theoretical level of reliability that satisfies current requirements.

Second step is to perform a real life experiment using prototype hardware. It involves both building a prototype and testing it. A measure of success would be obtaining matching performance to that of the modeled system.

Finally, a preproduction device must be created, using COTS components.

In the end, solving a problem of collision avoidance for UAVs in a densely populated, urban areas, will help “open up” the city skies, leading to safer, more reliable UAV use for urban mobility applications.

Acknowledgements

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The linkage among social networks, travel behavior and spatial configuration

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Social Travel Behavior (STB) is an emerging research field that seeks to analyze travel patterns as derived from social structures, for example, online social networks. As a result of rapid advances in Information and Communications Technology (ICT) over the past decade, social networks have begun to morph away from traditional structures into new alternative dynamic ones, such as those based upon internet relationships. An enormous amount of human capital is now invested in social networking sites (SNS), most notably Facebook. Each online social network encompasses social capital composed of weak and strong ties and a large and heterogeneous stock of information, some of which carries spatial context and implications.

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Enhancing Sustainable Mobility
A Business Model for the Port of Volos

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Abstract

The current paper concerns the investigation of the possibility of implementing Public Private Partnership (PPP) in the Port of Volos and eventually, the development of a business model supporting it.

For this purpose, extensive literature research was acquired, in order to fully comprehend the organizational schemes and state of practice of PPPs, their general features, as well as assess their efficiency in certain port functions and services. At the same time, the corresponding legal and policy frameworks were also studied, applying in international and Greek case studies.

Additional research was conducted, aiming at the functions of the organization, where a private involvement would potentially benefit the organization itself, as well as the rest of the stakeholders. This part of the research included interviews with key staff of the Volos Port Authority and local travel and port agents and the completion of survey questionnaires by a random sample of 100 passengers, during afternoon hours. The interviews were focused mainly on the Port Authority's operation, while the questionnaires were focused on the port infrastructure, the provided services and the satisfaction of the passengers in regard to these factors.

The collected data were analyzed, using a modified version of Analytic Hierarchy Process (AHP) to decide the importance of certain port functions and services. Subsequently, three possible ownership models were formulated. The proposed models were the current one, a landlord model and a combination of the current one with some level of privatization of port services or facilities. Based on literature research, their effectiveness on selected port functions and services was evaluated.

The results of the aforementioned process indicated, that the landlord ownership model would be the most effective for the particular case of Volos Port Authority, followed by full privatization, with the current model as a close third possibility. More specifically, the landlord model seemed to perform better in improving both the operation of the organization and the level of passenger satisfaction, through its increased flexibility, the possible segmentation of services, increased capital investment and a reduction of bureaucracy. Using these results, a business model was formulated, based on the Business Model Canvas.

Keywords: Public Private Partnership, privatization, business model, Port of Volos

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1. Introduction

In recent decades, there has been an increasing interest in Public Private Partnerships. Public Private Partnerships are collaborations between the public and private sectors, aiming at developing infrastructure or providing services (Katz, 2006, Greek Ministry of Finance, 2006, Tan, 2012, ADB, 2008). This paper tries to answer the question of whether such a model could be beneficial for the case of the Port of Volos and which one in particular would work best towards that goal, while developing a business model to support this potential partnership.

2. Literature review

Many different forms of PPP schemes have been used extensively worldwide. This is mainly due to the advantages they offer to the public sector, such as additional funds (Tan, 2012, ADB, 2008), reduced long term costs (Deloitte, 2006), additional technical expertise (Tan, 2012) and increased efficiency (ADB, 2008). However, there are also some disadvantages. More specifically, the complex nature of such schemes may lead to prolonged negotiations and large consulting and legal costs (Tan, 2012). In addition, there are also the issues of potential profiteering (Tan, 2012) and the business venture's possible failure (Katz, 2006) to consider.

A lot of PPP models have been implemented in various sectors. In service contracts, the public sector subcontracts a project (the development of infrastructure or the provision of a service) to a private entity, which has the responsibility to complete it (UNESCAP, 2011, ADB, 2008). Management contracts are agreements in which a private partner agrees to manage a public service for a certain period (UNESCAP, 2011, ADB, 2008, Honk Kong Institute of Surveyors, 2009). "Brownfield" concession contracts are long term concessions of existing facilities. In this case the private sector undertakes the full responsibility (management, maintenance, possible future investments) of an existing public facility (UNESCAP, 2011, ADB, 2008, Honk Kong Institute of Surveyors, 2009, Pagano, 2010). "Greenfield" concessions are similar to the previous model, but in this case the private sector has to contribute financially in the construction of the facility (UNESCAP, 20011, ADB, 2008, Honk Kong Institute of Surveyors, 2009, Pagano, 2010). In the Joint Venture model, the private and public sectors undertake a business venture and for this purpose they form a corporation which is responsible for its completion and management (ADB, 2008).

The process of PPP implementation consists of three distinct stages. The first one is that of the planning, in the second the negotiations between the public and private partners take place and in the third one the plan is implemented (Deloitte, 2006). During this process, an SPV (Special Purpose Vehicle) is founded by the private partners. The SPV is responsible for completing the project and subsequently managing the facility or providing the service. Among the shareholders are the investors, the private partners and other entities involved in the project, such as the public sector (UNESCAP, 2011, Greek Ministry of Finance, 2006).

In the port sector, the main PPP models used are Greenfield and Brownfield concessions and Joint Ventures (Farrell, 2011, Turpin, 2013). These are usually applied to container terminals, mainly due to the higher profits they offer to the investors. Another reason is that there are concerns about the concession of port services to the private sector, so that limits the available options mainly to cargo related services (Farrell, 2011).

Based on the degree of private sector participation, there are four port ownership models. The public service ports, which are ports in which the public sector holds a dominant role. The tool ports, where the public sector provides all the infrastructure and equipment necessary for the provision of port services, whereas the private sector provides the workforce. The landlord ports, where the private sector is responsible for the management and maintenance of the port facilities, as well as the workforce, while the public sector sets the rules and decides between potential partners. The last ownership model is the fully privatized port. In this case the public sector isn't involved in any way, except for protecting passenger and customer rights and keeping possible monopolistic practices in check (Gaur, 2005, Turpin, 2013).

Examples of PPP in the port sector are the ports of Rotterdam, Antwerp and Hamburg. These are the three busiest European ports in terms of cargo and operate under the landlord ownership model.

The Port of Volos is a corporatized public service port. Its passenger traffic comes mainly from the Sporades islands and cruise passengers during the holiday season and its container and cargo throughput comes mainly from the Thessaly region. Port data indicates that they both saw a rise before the economic crisis and a subsequent fall in recent years. It is also worth mentioning that part of the port area is sublet to private partners for commercial use. This area consists mainly of cafes and restaurants.

3. Method

At first, the services and facilities which would potentially benefit the most by a private sector involvement had to be detected. This was achieved by a combination of survey questionnaires and interviewing. The questionnaires were completed by a random sample of passengers, while the interviews were conducted with key staff of the Port Authority and some of the local travel and port agents. Subsequently, the data was gathered and analyzed using a modified version of the Analytic Hierarchy Process (AHP), originally developed by Thomas Saaty in the 1970s. Finally, based on the results of the aforementioned analysis and already known practices, three potential ownership models were evaluated and compared. These were the current one (public corporation), the commonly used landlord model and the current one combined with privatization of certain port services or facilities.

3.1 *Survey questionnaires*

This part of the research concerned the passengers using the Port of Volos. It was conducted from 10 to 22 November 2014 between 14:00 and 14:30. The sample was random and consisted of 100 passengers. The questionnaires were partly based on those of the Mass Transit System of Attica (OASA) and were adapted in order to better fit the specific case of the Port of Volos.

The questionnaire was made up of four parts. The first one included each passenger's personal information, specifically gender, age (18-25, 25-40, 40-65 and over 65) and level of education (elementary school graduate, high school graduate, university graduate). The second was about the passenger's satisfaction with the port facilities. In this part, the signage, the connection with the other means of transport, the waiting time utilization, the level of noise, the number and diversity of available activities in the port area, the existence of ATMs and the attractiveness of the port area were evaluated in a scale of 1 to 3, where 1 meant not satisfied, 2 indifferent and 3 satisfied. The third part included information regarding the purpose of the transport (work, education, entertainment, other reason), the means of transport used to reach or leave the port (transit, taxi, car or by foot) and the frequency of their transport (once a week, twice a month, once a month or rarely). In the final part, the passengers were required to rank certain aspects of port services in a scale of 1 to 7, where 1 meant that an immediate improvement or change was required and 7 represented the lowest priority. These were the cleanliness of the port area, the availability of port information, the accessibility of the port, the safety, the frequency of the service, the price of the fare and the general level of port services.

The data which were collected were analyzed, and it was found that in regards with passenger satisfaction with the port facilities, they were severely lacking in ATMs, waiting time utilization opportunities and in the number and diversity of the available activities. On the other hand, the passengers seemed to be generally satisfied with the signage and the connections with other means of transport, while being indifferent to the noise. In the fourth part of the questionnaire, the answers showed that the price of the fair demanded immediate attention, followed by the frequency of the service, while the improvement of the available information and port accessibility were considered low priority actions.

3.2 *Interviewing*

In this part of the research, interviews with key staff of the organization were conducted, as well as with local travel and port agents. The purpose of these interviews was to pinpoint the problems in the Port Authority's operation, and where a private involvement could benefit the organization, according to its executives.

The interviews with the port executives showed that the problems the port faces, are workforce shortage, outdated equipment, increased bureaucracy, lack of customs warehouses and lack of investment funds. The same problems were mentioned by the agencies' managers, who, while satisfied by the cooperation with the Port Authority, also brought up the high prices of the port services.

3.3 *Data analysis*

In the next part of the research, the collected data were analyzed. This was accomplished by using a modified version of the Analytic Hierarchy Process (AHP).

In this case, the hierarchical structure consisted of five levels. In the first, as the goal, was put the improvement of the port operation. In the second, in place of the criteria, were put the two parts of the research which were previously described, specifically the survey questionnaires and the interviews. In the third level, under the survey questionnaires, are found the second and the fourth part, namely the passengers' satisfaction and the port services ranking. In the fourth level, under the second and fourth parts of the questionnaire are found the items included in those parts, while under the interviews (which didn't have a third level sub criterion) can be found the problems that the executives and the agents brought up. In the last level are the three different scenarios which were examined in this study. These were the current ownership model, a landlord model resembling that commonly used in the EU and the current model combined with privatization of some port services or facilities.

In this particular study, the data from the survey questionnaires and the interviews were combined and used in the pairwise comparison in place of the selected experts' opinions. This was done by comparing the amount of answers each item received or how many times a problem was mentioned during the interviews. The relative importance was decided by dividing the number of answers or mentions the items being compared received. This however led to different scales for each part of the questionnaire and the interviews, as the difference between the most and least answers varied in each case. So the three scales (one for each part of the questionnaire and one for the interviews) that were created during this process, were normalized in a common 1 to 10 scale, resembling Saaty's 1 to 9 scale. In the new scale, 1 represented equal importance, while 10 represented the maximum possible difference of importance between the two items. This process was used only in the fourth level of the hierarchical structure, as the items of the upper levels were considered of equal importance.

After the setting of weights to each item, the evaluation of the alternatives took place. This was not done using pairwise comparisons, like in the original AHP method, but by evaluating their potential efficiency in the improvement of each element of the hierarchical structure based on literature and known practices. For this, a grade was put on each scenario in a 1 to 5 scale, where 1 means "not effective" and 5 "very effective". These grades were then multiplied with the weight of each element of the structure and the products were added to produce the final grade. The scenario with the greatest sum was considered the optimal one.

4. Results

The results of the research showed that between the three scenarios, the landlord model was the one which addressed the issues the port is facing in the best possible way, leaving behind the other two scenarios.

This model could help with the lack of workforce through the concession of the services where extra workers are needed, at the same time offering more job opportunities. It has been also shown that this practice could lead to better trained and more efficient workforce due to the private partner's expertise (ILO, 2008, Mistarihi, 2013).

The landlord model could work in a similar way in regards with the outdated equipment and the lack of investment funds. The additional funds that the private partner would contribute, would benefit the port, as they would be invested in new and better equipment and facilities in order to ensure higher profits through the rise of the level of service.

Finally, the issues of the frequency of service, the price of the fare, the waiting time utilization opportunities and the number and diversity of the available activities were addressed together. The frequency of service and the price of the fare are difficult issues to deal with. This is because, due to the imperative need of a means of marine transportation from the Sporades islands to the mainland, the service cannot be operated under market rules. This means that competition cannot sort out these issues in this particular case. The low level of profit is also the reason of the low frequency of service and the high prices. For this reason, it was suggested that a solution similar to that of the Maldives could be worked out. In that case, due to similar problems, the government gave to the ship owners land on certain islands to develop tourist resorts (ADB, 2014). In the case of Volos, part of the port area could be conceded to the ship owners, in order to outweigh the low profits (or losses) and in exchange raise the frequency and lower the fare. At the same time, this could potentially raise the number of offered activities in the port area and make it more attractive and profitable. This solution was deemed as a very efficient one, since it effectively deals with many problems of the port.

Based on these results, the Business Model Canvas was used to put together a business model. The key activities of the model were the concession of parts of the port area to a private partner, the concession of the container terminal, the adoption of a landlord model and a more market oriented management. The key partners include ship owners, potential investors and specialized service companies. The revenue streams are mainly the profits from the concession of the port area and those coming from cargo and passenger transportation. The key resources consist of the personnel, the investment funds the equipment and the infrastructure.

5. Conclusion

The current research tried to recognize the issues the Volos Port Authority is facing, and increase its operational efficiency by tackling them through a change in its ownership model. The ultimate goal was to formulate a business model incorporating the changes in ownership and policies suggested by the research. It was shown that a landlord model could work towards improving many of the problems recognized.

The next step could be a feasibility study of the suggested ownership and business model, delving more into technical details and dealing with the actual social and economic issues on a more practical level.

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