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OPTIMIZATION OF DECISION-MAKING IN PORT LOGISTICS TERMINALS: USING ANALYTIC HIERARCHY PROCESS FOR THE CASE OF PORT OF THESSALONIKI

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The management models pursued in logistics terminals determine their performance to a great extent. Terminals managed by public actors usually incorporate more social criteria into their decision-making processes. In addition, private management focuses on economic viability of the initiative. Decision-making is a complex process regardless the structure of management or the decision models useddue to the fact that a wide range of diverse criteria are embedded into this process. The objective of this paper it to determine a prioritization of a set of alternative options for investment projects which were suggested by port executives taking into account criteria and evaluation that have already validated by them. In order to perform the analysis a multi-criteria decision-making model was used: the Analytic Hierachy Process. The outcomes support a low-biased and efficient strategic planning through a balanced decision-making framework.

Keywords: ports; decision-making; AHP; logistics teminals; management structures; Thessaloniki

1. Introduction

The management of transport infrastructure is an important issue for the added-value it offers. Transport terminals, corridors, ports require efficiency in management in order to deliver high performance which sometime is perceivable to the national gross product. Freight transport corridors include interconnection points that are characterized by the operation of a range of freight operations (TRB/NCHRP, 2004). A common management project implies the role of public sector as infrastructure provider and regulatory framework provider whereas the private sector undertakes the transport service (World Bank, 2005). Echhardt et al argue that one of the most sustainable management models is the combination of public and private actors: in the upfront phase the public sector is in charge. Normally, when market demand is stimulated, then the private industry takes the lead and the public sector has supportive and legislative role [3].

However, the management structures of terminals may affect also funding of investment projects. Private owned companies may usually take decisions for funding faster than public owned companies due to political relationships or accountability issues to administration, etc. On the other hand, in enterprises which are managed by public actors there are more long-term investments. They also tend to care more the socio-economic perspective, while private owned companies tend to focus on profit (fig 1). There are many paradigms sourcing from literature that describe the management structures of transport infrastructure and any impacts that might have been identified (Eckhardt et al, 2013):

- C-Business project (2008-2011) investigates infrastructure networks and their ownership, governance and operation models. The project evaluated the advantages and disadvantages of different ownership and governance models of technical in frastructure networks. The project conducted SWOT analyses of these models and highlights the main differences between different ownership and governance models.
- ENABLE project (Permala and Rantasila, 2010):

- Inland waterway operator Rhinecontainer aims to create co-operation between deep sea and inland terminal operators to manage congestion in ports. Rhinecontainer uses operational agreements in order to form strategic partnership with terminal operators to guarantee service availability and quality of service. Service level agreements (SLA) are developed and key performance indicators (KPI), and they work as framework of rights and obligations between the engaged parties.
- BoxXpress operates train connection between sea ports and inland terminals. Eurogate Intermodal GmbH coordinates the transport chain. There are also other companies that undertake relevant operations. The success factors include strong operators that are interacting each other and the leadership of one operator which coordinates the alliance.

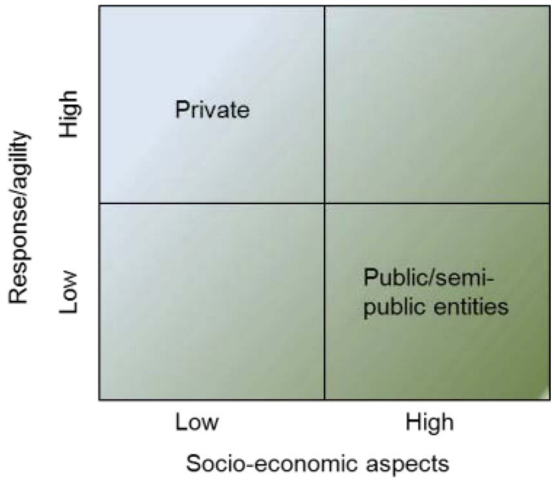

Figure 1. The characteristics of terminal ownership regarding corridor development [3]

Four main management structures of transport infrastructure are indicated that are applied worldwide. This diversification relies on the scope and the objectives that each management structure represents. The management structures identified are (Arnold, 2006):

- Project coordination
- Legislative model
- Consensus-building
- Public private partnerships (PPPs)

The management of a transport infrastructure, i.e. a corridor or a terminal, is either more general, based on geographical criteria, when infrastructure managers, academic, regional, national and EU-level actors are active and they all have significant role. On the other hand, the development is more based on specific business and this isusual when the operators are the main actors.

The decision-making is also a challenging process that is impacted by and impacts the management structure. Issues such as environmental protection, energy conservation, modal split and competitiveness, improvement of accessibility and regulatory restrictions, affect the above processes (Nathanail et al, 2011). This complexity in the decision making is also met in transport corridors, where, apart from the roadway itself, management plan has to deal with issues such as land use, access management, street networks, etc., complicating the texture or content of decisions (Williams and Hopes, 2007). The strategic framework for this process is formulated by policy makers and planning stakeholders referring on the development of the needed infrastructure and the system operation (Adamos et al, 2012). Decision-making could also regard issues different than those aforementioned.

The main objective of this paper is to use a multi-criteria decision-making framework which is the Analytic Hierarchy Process in order to determine a prioritization of alternative investment projects that addresses the problem of the increase of port performance. To this end, a review of decision-making methods in port logistics terminals is made combining management structures, decision-making models and expected impacts on terminal's performance. Then, the methodology is described regarding the evaluation framework and the survey's methodological steps. Results and findings of the analysis are presented resting on the interviewee's statements and criteria validation. The conclusions refer to the discussion about the results and any constraints that affect the research process are highlighted.

2. Review of decision making methods in port logistics terminals

2.1 State of the art

Based on the literature review, the decision making model adopted by port logistics terminals is interrelated with their management structure. In most of the times, the final decision is taken after many plenary meetings amongst the management authority, the main stakeholders and shareholders and the transport planning department from the part of the government. In addition, the contribution of the local or regional authorities (e.g. city council) is requested, as the interaction amongst the port operations and the socio-economic development of the adjacent area is significant. Moreover, in many cases the role of the experts is required and then, some private planning and development companies are involved, as well, often configuring some kind of consulting board or committee. Thus, the decision making, especially when some high investment plans are involved, constitutes a very complex, time consuming and sophisticated process. Except for the investment height, the responsibility of the decision makers is increased equally to the effect of their decisions on the environment, the everyday quality of life level, the socio-economic climate and the business trends of the area of influence (Brauers, 2013).

The most common decisions taken are related to the investment of an amount of money, the renovation of old infrastructure or obsolete electromechanical equipment, the relocation of services to different office buildings and the restructuring of the terminal's inside transportation plan. However, in some cases, major investments have to be determined, concerning the spatial development of the port or the establishment of new infrastructure (e.g. new berths and quays) and the purchasing of new pieces of equipment (e.g. new cranes and straddle carriers) or even the updating or integration of the utilized software (e.g. warehouse management and monitoring system) towards the upgrading of the provided services, in order for the port logistics terminal to enforce its position against competition. In those cases, the role of the government is fundamental. In other cases, in the context of modelling, some algorithms are used in order to reach optimization, such as the minimization of cost or the maximization of the terminal's throughput, also applying other methods and techniques, such as the economies of scale or the redesigning and updating of the terminal's business model and Master Plan according to the external market trends. For example, in the port of Aqaba, Jordan, they used linear programming to build transportation and transshipment models in order to test whether the existing actual costs to transport the major Jordanian exports and imports are optimal, resulting in the suggestion that Jordan should develop its own shipping fleet to cut drastically the cost of importation through means of economics of scale and bulk shipping (Karasneh, 2012).

So, in most of the cases, due to the involvement of many different stakeholders, the decision making model is structured as a multi stakeholder, multi criteria analysis or evaluation process of suggested scenaria. Trying to find the best alternative, the process involves the setting up of a number of evaluation parameters (criteria and 'their' indicators) and the determining on their significance (weight) through the Analytic Hierarchy Process (AHP), allowing the group of experts and involved stakeholders to contribute by presenting their individual approach, like in Vietnam sea port development programme (Phuing and Chapman, 2006).So the AHP all by itself may be considered as an important decision making tool, independently of the type (administrative authority, managing body or customer), origination (public or private) and number or group(s) of stakeholders involved. Moreover, othere fields of evaluation may concern the modelling of the infrastructure and equipment. Nathan Huynh and Jose M. Vidal have developed a novel agent-based approach to model yard cranes, where each crane acts as an autonomous agent that seeks to maximize its utility. A key component of the proposed agent-based simulation model is a set of utility functions that properly capture the essential decision making attributes of crane operators in choosing the next truck to serve. The developed simulation tool can be used by terminal management to make strategic planning and/or real-time operational decisions to improve and optimize yard crane operations (Huynh and Vidal, 2012).

Nevertheless, the past experience has indicated that different business models and management structures applied in port logistics terminals lead to accordingly different decision making models, while the orientation of the involved stakeholders has great effect on the final decision taken by the responsible bodies. The private sector is mostly interested in the economic profit and the level of provided services, while the public domain is primarily affiliated the social criteria and to the effect of decision making on politics. Those parts' objective goals and pursuits hardly ever coincide with each other, thus, when it comes to combine them, the final decision should be independent from "external" influence. The benefit of the multi stakeholder multi criteria decision making (MSMC D-M) lies in the fact that the final solution is commonly accepted as it represents the majority's point of view, while in most of the cases, it is does not comply with individual benefits, profit and pursuits set by the involved stakeholders.

Within the next paragraph, based on the CLOSER-project results and findings, the cases of the selected port logistics terminals in Helsinki, Finland, in Constantza, Romania and in Thessaloniki, Greece are analyzed more thoroughly in order to investigate the role of each terminal's management structure in the decision making and, eventually, on the port's role in the supply chain (Eckhardt et al, 2012; Gogas et al, 2013).

2.2 Highlights from the selected sites

2.2.1 Helsinki logistics port terminal

The logistics terminal is situated in the Vuosaari port area which is owned by the municipality of Helsinki. Vuosaari freight terminal started operations in late 2008; before 2008, the freight terminal was located within the city of Helsinki. The municipality of Helsinki, in collaboration with the port authority, has set the Board of Municipal Enterprises to manage several municipal-owned companies, undertake the port's operations and also be in charge of planning and investment initiatives regarding the port area, supporting private operators' initiatives.

Vuosaari Harbour operates under the landlord ownership and management principle. The Port of Helsinki manages the infrastructure and the rest land area and leases it to private operators. Operators (shippers, LSPs, freight forwarders, etc.) own the port superstructure and sign bilateral agreements (contracts) with the management authority (Port of Helsinki). In addition, there are several other stakeholders involved in the port freight activities, such as logistics services providers, warehousing, stevedoring and freight forwarders.

Private companies are the operators of the superstructure components, such as cranes, terminals, machinery, cargo-handling equipment and information systems. The Finnish state (national authorities) is responsible for the customs clearance of goods transported. Finally, the corresponding ministry is also responsible for monitoring the legal compliance of operations. Concerning funding and economical support, there is no public subsidy, but the government launches national projects of road and rail infrastructure outside the port area facilitating interconnections (Eckhardt et al, 2012; Gogas et al, 2013).

All the involved stakeholders share mutual interests and views regarding the port future evolution. In order to foster these targets, communication channels are developed with common procedures followed by different cooperation bodies: operational level meetings with other port operators (operational level), meetings in (higher) executive level and a cooperation forum organized between actors.

The management structure of the terminal is dictated by the municipality law of Finland which stipulates that ports are driven to the municipalities of the cities where they are located. This policy will ensure competition neutrality. This generic policy set by the Finnish state leads to higher and more neutral competition between port terminals of the country. Each municipality manages their 'corresponding' port autonomously, setting goals for each enterprise under a common national port policy. This acts as a leverage of the private interest leading to more economically and operationally sustainable approaches to entrepreneurship.

Based on the most updated port's statistical yearbook, the economic outcome of the port's operations is positive and secured against the impacts of economic downturn. Investments, although reduced, are still made and the operational outcome is positive feeding the city's economy, as 15% of total income is channeled to the municipality as a revenue stream. Despite crisis repercussions, cargo traffic is slightly ascending during the last five years. This outcome is promising, given that the most intense impacts of the economic recession have been incurred on international trade. The market share of freight port of Helsinki is over 50% within the national context. Also, during the years from 2010 to 2012, an increase has been identified in container traffic. The statistics bear witness of the economic viability of the port, being secured and strengthened through the economic recession, indicating operational effectiveness and management efficiency (Eckhardt et al, 2012; Gogas et al, 2013).

2.2.2 Constantza logistics port terminal

Since 1998, the port of Constantza constitutes a joint stock company, under a PPP management scheme. This implies that both public organizations or bodies and private companies take part in the decision making. Especially concerning the corridor development concept, the private initiative is fundamental, always taking into consideration the EU transport policy and actions on international intermodal corridor development. As per the ownership status, it is public-private and is owned by the Romanian State which is responsible both for the configuration of the regulatory and operational framework. The management of the port and its respective operations is undertaken from the National Company Maritime Port Authority S.A. of Constantza (NCMPA) and the Romanian Naval Authority (RNA), under the supervision of the Romanian Ministry of Transport and Infrastructure (MTI) (Eckhardt et al, 2012; Gogas et al, 2013).

According to the adopted "landlord port" business model, the port authority is responsible for the building of platforms, piers, quays and wharves which are either rent or leased by the terminal operators (e.g. stevedoring companies). According to the management structure, the port authority (NCMPA), being subordinated to the MTI, has the prevailing role in the decision making concerning operational and business planning, while also being in charge of policy making and marketing strategies. Those stakeholders participating in the port's management structure consist of terminal operators, owners and users, information, infrastructure and equipment providers (e.g. railway organizations, information system administrator and truck operators), transport and stevedoring companies and also local authorities and civilians.

Towards the achievement of a sustainable development and a win-win strategy, any coordination and collaboration issues based on the established cooperation and procedural framework, as well as any agreements, partnerships and negotiations amongst stakeholders, according to everybody's role, tasks, jurisdiction and duties, are identified within the Master Plan of 2001-2002. It was created by the MTI and the NCMPA, based on the mutual agreement, approval and respect from the part of all the stakeholder groups, also participating in the management structure. According to the management structure, all the stakeholder groups participate in the decision making concerning all the geo-economic development issues. The Master Plan includes all aspects associated with policy making, economic and market development, geographical expandability and infrastructure renovation and upgrading (Gogas et al, 2013).

The "opening" to the private investors and the creation of the Master Plan enabled the processing of many infrastructural projects leading to the development of the port and its connections to the national and international transportation network. In particular, both the motorway and railway network connectors have been upgraded during the last decade, while the market share has also been considerably broadened and the traffic recorded a 5% annual increase from 2001 to 2009, until the beginning of the recession. Furthermore, the transformation of the port to a free-zone in 2007 immediately gave a 10% boost in the traffic flows handled by the Port of Constantza. After the recession, the business and organizational model continues to provide extra credit to the port and also the recovery of the lost workload has already started, making it a success story.

2.2.3 Thessaloniki logistics port terminal

In Thessaloniki, the port authority (ThPA SA) is the decision-making and executive body of the port. ThPA SA belongs approximately by almost 75% to the Hellenic Republic Asset Development Fundand by 25% to rest shareholders (private sector). However, a strong advisory board was also established, the Port Development Council. It constitutes a non-legally recognized advisory group, without managerial and decision-making jurisdiction, developed through multilateral agreements of common interest between stakeholders under the 'win-win' strategy and towards the growth of Thessaloniki's port. This council is assembled by almost fifteen members from the ThPA SA management board, regional and local authorities, trade and logistics associations, transport operators, customs brokers, etc.

The land and the infrastructure of port area is owned by the Greek state (national government) and it is managed by ThPA SA. Private companies have signed agreements with ThPA SA to use and exploit equipment and infrastructure under the framework of private agreements.

The stakeholders involved in the port operations are: European Union, national government, local and regional authorities (municipality of Thessaloniki), terminal manager and operator (ThPA SA), freight forwarders, transport and logistics operators, rail operators (O.S.E.), stevedores and customs officers. Moreover, as the greek state is holding a significant part of ThPA SA shares, decision-making of ThPA SA is dependent on political expediency of each national government.

Concerning the effect of the management structure and decision making in the port's development, the port of Thessaloniki constitutes a special case where the new management structure resulted in the growth of port product since 2001, when the managing body has transformed into a SocieteAnonyme. A continuous increase is recorded until 2007, followed by a hard drop, indicative of the change in the economic environment. However, after 2008 a slight increase is identified in all sectors (economic, operational throughput) of the managing authority. The involvement of private bodies into the management of the port combined with the transformation into a less public-interest company had been key drivers towards the goals which were set (economic viability and maximization of operational product). Furthermore, the direct involvement of the private sector (actually the port customers) through the port development council is considered as a best-practice as indicated by the level of service. This advisory board composed by all the involved stakeholders leads to the alleviation of issues identified regarding the port, enhances the efficiency, facilitating also private sector operations (Eckhardt et al, 2012).

2.3 Main findings

In this section, based on the case study experience, a number of trends configuring the suggested management structure of port logistics terminals are indicated.

As per the ownership status, the PPP model, open to every potential stakeholder seems to guarantee mostly the legal support from the part of the state, while keeping alive the interest of private investors and shareholders. In addition, the privatization of certain domains, such as the telecommunication service, has proven to be operationally beneficial, as the promotion of private initiative leads to the increase in competitiveness and eventually to the enhancing of the level of provided services.

Pertaining to the management task of the terminals and the decision making processes, the involvement of all stakeholders seems that bridges the communication gaps and eliminates monopolies and rivalries, providing solutions acceptable and approved by the majority, in favor of the terminal's benefit. Nevertheless, the obligations, attitude, tasks and jurisdiction of each stakeholder must be identified and well determined in a commonly agreed, targeted document, usually a Master Plan, in cooperation with all the involved operators. Also, any plans concerning infrastructural and operational development could be included in such documents.

3. Methodological approach

3.1 Multi-Criteria Analysis and Analytic Hierarchy Process

In order to capture the particularities of each of the options that constituted the main problem, a multi-criteria evaluation tool was needed. Decision-making is a multi-dimensional process that embeds the interaction of different kind of actors or the synthesis of diverse components. Operational research contains plenty of tools that support balanced strategic planning and decision-making.

Multi-criteriaanalysis (MCA) is a common decision-making method that is used in operational research and its main objective is to evaluate multi-dimensional projects which are intertwined with multi-option strategic planning. The general methodological steps that are pursued when using multi-criteria analysis method are:

a. model structuring and objective(s) definition,
b. determining of the alternatives that each one of them meets the objectives of the problem,
c. conception of the criteria in terms of which the evaluation of each one of the alternatives will take place,
d. building of the evaluation matrix and finally,
e. evaluation of the alternatives through the criteria shaped.

The criteria reflect the dimensions of a decision-making problem that is governed by objectives. The fact that multiple criteria of multiple stakeholders are used seems very useful especially within the context of logistics planning, where multiple stakeholders, conflicting interests and criteria represent the nature of such issues (Nijkamp et al, 1990).Global bibliography contains more than 40 evaluation approaches of multi-criteria decision-making methods, some of them more complex whereas others are identified as simple prioritization methods (Charnes and Cooper, 1961; Nijkamp, 1986).Such techniques offer the opportunity of including the evaluation of both qualitative and quantitative evaluation indicators in the same model developing also discrete evaluation criteria in a multi-aspect problem.

One of the most used methods of multi-criteria analysis is Analytic Hierarchy Process (AHP). The AHP is a multi-criteria decision making method that enables the evaluator to perform comparisons between a set of criteria that assist them to prioritize all the available strategic alternatives. It was dveloped by Saaty and it is considered as one of the most practical methods of multi-criteria decision-making (De Brucker, 2004; Saaty, 1972). The method has been widely used in site selection (Saaty, 1977), strategy selection (Önüt et al, 2010; Chen and Wang, 2010), in sustainability evaluation (S. Li and J. Z. Li, 2009), energy selection (Su et al., 2010) and many others.

One of the advantages of AHP is that it allows a hierarchical structure of the criteria. This provides deeper focus on objectives, alternatives, criteria and sub-criteria and more efficient allocation of weights. The structure issue is of utmost importance as different types of structures might result in different final rankings. As an example, many AHP specialists argue that some criteria with a large number of sub-criteria tend to receive more weight than the ones that are less analyzed (Stillwell et al, 1987; Weber et al, 1988).

In a simple multi-criteria decision making problem all the above elements of the matrix are expressed in the same unit (e.g. euros). Sometimes, though, some criteria may be expressed in different units reflecting time, environment-based units, qualitative indicators on political criteria, etc. AHP facilitates the resolving of decision-making problems through the quantification and normalization of values.

The structure of a typical problem regards a number of i.e. M alternatives and N criteria. The pair-wise comparison matrices consist of MxN elements. The performance value of the i-th alternative in terms of the j criterion is denoted with a_{ij}. Wj denotes the weight of criterion Cj. As such, the decision matrix below represents a typical multi-criteria decision making problem:

$$A = \begin{array}{c} \begin{array}{ccc} C_1 & \dots & C_N \end{array} \\ \begin{bmatrix} a_{11} & \cdots & a_{1N} \\ \vdots & \ddots & \vdots \\ a_{M1} & \cdots & a_{MN} \end{bmatrix} \end{array} \quad \text{for i=1 to M and j=1 to N} \tag{1}$$

The core objective of the problem is to decide which alternative of M ones is the best to opt for in order to fully meet the problem's objectives. A slightly similar approach of the problem is to determine the relative significance of each of the alternatives comparing them each other in terms of N criteria (Triantaphyllou and Mann, 1995).

Sometimes, absolute values could not be assigned to certain qualitative indicators. As such, it is the determination of relative importance of the alternatives in terms of certain criteria that facilitates decision making. This is exactly the role of pair-wise comparison; to determine the relative importance of each alternative in terms of each criterion. Practically the common statements that reflect the choices in the pair-wise comparison are "A is more important than B" or "A is of the same importance as B" or "A is less important than B" (Triantaphyllou and Mann, 1995).

In an attempt to facilitate this type of comparison, AHP could run more smoothly using ratio scales. This type of scale represents a set of discrete choices available to the decision maker and a set of discrete numbers representing the choices that express the relative importance of one choice upon the other in terms of criterion studied. Verbal statements as the "A is of the same importance as B" are 'converted' into numeric values. This scale is proposed by Saaty (1980). According to Saaty the numbers that are used in pair-wise comparisons and form the scale are: {9,7,5,3,1,1/3,1/5,1/7,1/9}. Even numbers could also be used except for the odd ones, in case of expressing an intermediate evaluation. The used structure of scales and the numbers that are generated are based on psychological theories (Triantaphyllou and Mann, 1995).

Given the (1), the preliminary priorities of the alternatives are calculated with the use of the geometric mean of the rows:

$$P_i = \sqrt[N]{\prod_{j=1}^{N} a_{ij}} \tag{2}$$

After the calculation of each priority P_i, i=1 to M, normalization is achieved through dividing priorities with their sum.

$$p_i = P_i / \sum P \tag{3}$$

The final priorities vector for each comparing option is then produced, $\vec{p} = (p_1, p_2, \dots, p_N)$.

The next step is the estimation of the consistency level of statements, namely a consistency check of the outcomes of the pair-wise comparisons. AHP methodology allows for slightly non-consistent pair-wise comparisons. Saaty(1980) suggested a Consistency Index (CI); this is estimated by multiplying the sum of each column of the pair-wise matrix with the resulting vector of priorities $\vec{p}$ of each one of the matrix components. The value which is generated is the λ_{max}. The CI is calculated by the formula (Saaty, 1972):

$$CI = (\lambda_{max} - N)/(N - 1) \tag{4}$$

where N is the dimension of the matrix.

Finally, the Consistency Ratio (CR) is estimated through:

$$CR = CI/RCI \tag{5}$$

RCI is the Random Consistency Index, which represents that average CI of 500 randomly filled matrices. Saaty calculated the RCIs in combination with the dimension of the pair-wise comparison matrix (Saaty, 1980).

Table 1.RCI values for different values of indicator N

N	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
RCI	0	0	0.58	0.90	1.12	1.24	1.32	1.41

When it comes to the synthesis of results and the determination of the final prioritization, if a problem consists of M alternatives and N criteria, then there should be N judgment matrices (one for each criterion) of MxM elements and one M judgment matrix of NxN criteria. In this respect, the final priorities of the alternatives evaluated in terms of the investigated criteria are determined through the following formula (Saaty, 1980; Nathanail et al, 2014):

$$A_{AHP}^{i} = \sum_{j=1}^{N} a_{ij}\, w_j \qquad i=1,2,3\ldots,M \tag{6}$$

3.2 Scenarios development and data mining

The development of this strategic approach required a data mining process that was taken forward through a series of interviews with port executives. The data mining process was carried out during 2013 and included the conduction of two interviews with theHead of Strategic Planning, Marketing & Sales Department at Th.P.A. SA. This department is responsible, among else, for the shaping and analysis of strategic planning for Th.P.A. SA determining and prioritizing the investments needed for projects.

The objective of these interviews was to discuss the range of options in order to achieve better port performance for the freight terminal regarding the economic, transport and energy-environmental sectors of the port. In this regard, three scenariosof alternative options were analyzed that constitute broad project development and robust funding sources. The options were the following ones:

- Development of a dry port in the outskirts of Thessaloniki city, close to national road networks and the rail network in the west part of the city. This action requires the mitigation of a wide range of port activities within the existing area and transfer of them to the dry port. This option is expected to decongest the urban area contributing in environmental recovery and more efficient port operations. This should be called hereinafter ‘Dry port’ option.
- Acquisition of additional, advanced and efficient equipment and development of new infrastructure projects in port area. The equipment should include yard tractors, cranes, forklifts, etc. Basic infrastructure projects could encompass pier expansion, the development of new logistics or warehouses, deepening of the harbor in order to accommodate larger cargo ships, etc. This is expected to raise efficiency through upgraded level of service and enhance productivity while slightly mitigate environmental burden. This option is hereinafter called ‘Do something’ option.
- Broad intervention in order to upgrade the environmental profile of the port aiming at increasing energy-efficiency. Apart from the renewal of the equipment to ‘greener’ one, a set of projects could assist the environmental upgrading of the port: implantation of new technologies based on reduction of energy consumption and on-site energy generation such as renewable energy production and use (electricity from photovoltaic systems, wind and biomass, biofuels use and processing, renewable heating and cooling) and energy efficiency in buildings, processes, transport and logistics. This option is called ‘Green’ option from now on.

The options were structured in compliance with the port specialist within the context of investigating the hypothesis of where to channel an available funding. The objective of the problem was the investigation of ways to enhance the performance of the port in terms of financial viability and growth, social acceptance, tackling of the port-oriented environmental pollution, increase in energy-efficiency and sustaining level of service. The scenarios of alternative options were also shaped in terms of current and future needs, local and regional spatial trends, economic perspectives, urban transformation and international trade potential. The criteria were conceived through relevant literature and validation by port executive which was the evaluator. In a study of Gogas and Nathanail (2010) suggest a multi-criteria framework for the evaluation of the performance of freight centers that highlight the business and competitiveness point of view of freight nodes such as ports, freight villages, logistics centers, etc. In another study Eckhardt et al. (2012) recommend a quantitative framework for the assessment of long and short distance interconnection nodes. IMONODE project (2005a; 2005b) suggests an evaluation framework tailored for assessing national and intermodal freight terminals across initially developed for central and south Europe. Port executives, validated these findings producing the final criteria:

- geostrategic location,
- level of service,

- competitiveness,
- improvement of the quality of life,
- safety and security,
- socioeconomic development.

Within the context of AHP, the port executive made the pair-wise comparison in order to come up with a prioritization of alternative options of investments in terms of the criteria selected.

3.3 Port of Thessaloniki

The port of Thessaloniki is located at the central-west side of the urban agglomeration of Thessaloniki. The port is located at the city center, about 25 kilometers from Thessaloniki's international airport and about 3 kilometers far from the central railway station. As such, the port could provide a combination of transport modes: maritime to road, rail and air transport. It has fair access to the west road entrance which is part of the main road link between Thessaloniki and Athens. This national road axis is called P.A.Th.E. highway network (Patra – Athens – Thessaloniki – Evzoni). Thessaloniki serves as a vital node in the national road network. Also, the city of Thessaloniki is almost in the middle of the road axis Egnatia highway connecting the eastern with the western borders of Greece. Moreover, the port of Thessaloniki facilitates freight forwarding to Balkans (Albania, FYROM, and Bulgaria) and southern central Europe via its direct linkage through European corridor X (Christiansen et al, 2012).

The management authority for the port of Thessaloniki is Thessaloniki's Port Authority SA (ThPA SA). ThPA SA was established in 1999 as a private entity (private law of public utility) with managing and operating responsibilities of port facilities. The land and infrastructure were conceded by the Greek state to ThPA SA (according to concession contract signed on June 27^{th} of 2001) for the operation, management and exploitation until 2041. Currently, the Greek state indirectly owns the majority of the shareholding of ThPA SA through the public-owned Hellenic Republic Asset Development Fund SA. Land and infrastructure belong to the Greek state too, but operations are being performed by ThPA SA as well as all other services provided. ICT-systems operation and maintenance are also subject to ThPA SA's responsibility (Christiansen et al, 2012).

4. Results

The Strategic Planning Department of Thessaloniki Port Authority SA should determine where to target funding regarding the aim of enhancing the performance of the freight port terminal through infrastructure and equipment project portfolio, ranging from longer term to short-term actions:

1. delocalization of most of freight terminal operations to city outskirts providing direct link to national and international road and rail corridors and reorganization of port's operations and activities both in supply and demand terms,
2. acquisition and operation of innovative and efficient port equipment resulting in wide renewal of the existing equipment in combination with targeted interventions to infrastructure (construction works) with view to higher capacity utilization and higher productivity,
3. upgrading of the environmental performance and energy-efficiency of the port through a wide array of actions leading to significant cost-savings, higher compliance with the environmental standards and higher social acceptance.

In order to assign weights to the evaluation criteria, the evaluator made pair-wise comparison between the selected criteria. The raw matrix is presented below:

Table 2. Final judgment matrix

	Geostrategic location	**Level of service**	**Competitiveness**	**Quality of life improvement**	**Safety and security**	**Socio-economic development**
Geostrategic location	1	1/7	1/5	1/3	1/7	1/5
Level of service	7	1	3	5	5	1
Competitiveness	5	1/3	1	3	3	1/3
Quality of life improvement	3	1/5	1/3	1	1/3	1/7
Safety and security	7	1/5	1/3	3	1	1/5
Socioeconomic development	5	1	3	7	5	1

The priority vector for the matrix above, calculated through (1), (2) and (3):

Table 3. Priorities matrix for the decision criteria

Criteria	Priorities
Geostrategic location	0.030
Level of service	0.334
Competitiveness	0.154
Quality of life improvement	0.054
Safety and security	0.095
Socioeconomic development	0.334

In order to test the consistency level, the Consistency Index is estimated through the formula (4). The indicator λ_{max} is estimated as follows: the sum of each column elements of the final judgment matrix is multiplied by the priority value of each criterion and then the components are summed up, according to the formula:

$$\lambda_{max} = \sum \sum_{i=1}^{n} a_{ij} * P_i \tag{7}$$

As such, λ_{max} = 6.386 and CI = 0.077.

The Random Index, according to table 1, forN=6 RI is 1.24. Finally, the consistency ratio (CR) is estimated by formula (5). Consequently, CR = 0.062. CR should be below 0.1. Nevertheless, some circumstances may allow higher values of CR, even up to 0.3 (Triantaphyllou and Mann, 1995; STRAIGHTSOL, 2012). The procedure is explained in detail by Saaty (1988).

The next step is to compare the alternative options with each other under each evaluation criterion. This step will show how relatively preferable is each alternative compared to the other when it is examined under the umbrella of diverse evaluation criteria. Practically, the 'dry port' option is compared to 'do-something' option and 'green' option. The final matrices and priority vectors become:

Table 4. Pair-wise comparison matrix and final weights of the alternative options in terms of criterion 'Geostrategic location'

	Dry port	Do-something	Green	Weights
Dry port	1	7	9	0.785
Do-something	1/7	1	3	0.149
Green	1/9	1/3	1	0.066

λ_{max} = 3.080, CI = 0.040 and CR=0.069. The initial analysis for this criterion showed an inconsistency with a CR>0.1. Taking into account the simple form of options and the fact that no particular circumstances run within this context, we went back and received new feedback from the evaluator.

Table 5. Pair-wise comparison matrix and final weights of the alternative options in terms of criterion 'Level of service'

	Dry port	Do-something	Green	Weights
Dry port	1	3	7	0.669
Do-something	1/3	1	3	0.243
Green	1/7	1/3	1	0.088

λ_{max} = 3.006, CI = 0.003 and CR=0.006.

Table 6. Pair-wise comparison matrix and final weights of the alternative options in terms of criterion 'Competitiveness'

	Dry port	Do-something	Green	Weights
Dry port	1	3	3	0.600
Do-something	1/3	1	1	0.200
Green	1/3	1	1	0.200

λ_{max} = 2.999, CI = 0 and CR=0.

Table 7. Pair-wise comparison matrix and final weights of the alternative options in terms of criterion 'Quality of life improvement'

	Dry port	Do-something	Green	Weights
Dry port	1	1	1/7	0.132
Do-something	1	1	1/3	0.174
Green	7	3	1	0.694

λ_{max} = 3.080, CI = 0.040 and CR=0.069.

Table 8. Pair-wise comparison matrix and final weights of the alternative options in terms of criterion 'Safety and security'

	Dry port	Do-something	Green	Weights
Dry port	1	1/5	3	0.188
Do-something	5	1	7	0.731
Green	1/3	1/7	1	0.081

λ_{max} = 3.065, CI = 0.032 and CR=0.060.

Table 9. Pair-wise comparison matrix and final weights of the alternative options in terms of criterion 'Socioeconomic development'.

	Dry port	Do-something	Green	Weights
Dry port	1	5	7	0.731
Do-something	1/5	1	3	0.188
Green	1/7	1/3	1	0.081

λ_{max} = 3.065, CI = 0.032 and CR=0.060.

As it was aforementioned, the priorities of the tables above are used to form the elements of the decision matrix. The final decision matrix and the final priorities (which are calculated according to formula (6) are:

Table 10. Final decision matrix

	Geostrategic location	Level of service	Competitiveness	Quality of life improvement	Safety and security	Socioeconomic development	Final weights
	0.030	0.334	0.154	0.054	0.095	0.334	
Dry port	0.785	0.669	0.600	0.132	0.188	0.731	0.608
Do-something	0.149	0.243	0.200	0.174	0.731	0.188	0.258
Green	0.066	0.088	0.200	0.694	0.081	0.081	0.134

Regarding the findings of the decision matrix, it is believed that the 'level of service' and 'socio-economic development' are the highest concerns for the evaluator regarding the performance of the port. Also, the 'competitiveness' criterion is ranked third according to weights ranking; this implies that the evaluator presented high concern to economy and business fields relating the performance increase with economic prosperity of the enterprise and business growth. The lowest rated criterion is the 'geostrategic location'. During the interview this criterion might have been anticipated as less generic criterion of low importance and that is slightly affects the performance of the port. An explanation could be given: there is low flexibility regarding the delocalization of the main port so the criterion mostly refers to the assessment of current location.

Another point that could be stressed is that the delocalization of the port's activities could better assist in the socioeconomic regional and national development. In this regard, it could be argued that this fundamental re-organization of the port's activities could allow room for higher growth perspectives while alleviating the urban environment from excessive traffic congestion and pollution. As someone may expect, the most suitable option towards the improvement of quality of life is the 'green' option, which contains explicit actions to this end. In addition, according to the evaluator socioeconomic development would rarely be impacted by the 'green' option. This could be interpreted that the local community would not capture any of the positive environmental impacts that could appear in the middle term.

Regarding the final outcomes, special attention could be paid on the prioritization weight of 'Green' option. This option indicates very low prioritization in all but the 'quality of life improvement' criteria. Within this context, it could be assumed that the option could have minimum impact on the level of service or on other sectors that are directly not elevant to society and environment.

5. Conclusions

The operational performance of private companies relies on their management structures and decision-making models to a great extent. This could be explained due to the fact that public managed companies are affected also by political trends and forces or social drivers. On the other hand, private companies wish to achieve greater operational profits. A similar situation takes place in management of logistics-based companies. Taking into account that logistics is a multi-dimensional sector and that sustainability is a new age culture that has recently been integrated into the business culture, there are many factors that determine the strategic planning for logistics and freight centers.

Logistics terminals, such as ports, that are managed by public actors pay attention not only to economic profits but on social cohesion and environmental alleviation. Sometimes local communities put pressure on politicians (or municipalities) trying to resolve issues that are caused by port activities. These actions are led by the fear of voting for local political actors. Therefore, the models used for decision-making in logistics terminals managed by public actors usually incorporate the social interest. In contrast, private sector focuses strongly on financial indicators, level of service and in general, company viability. Some companies though, are governed by the culture of corporate responsibility, namely actions addressing the society that stem from the corporate ethics. Besides, 'green concerns' is a characteristic of companies with high corporate ethics; aiming at environmentally and energy efficient operations.

This multi-dimensional issue is satisfactorily tackled by AHP, a multi-criteria decision-making model that integrates many different aspects of strategic planning allowing almost nospace for biased evaluation. However, in order to ensure more robust and accurate evaluation, this analysis could be combined with the incorporation of more stakeholders so as to define the stakeholder that is benefited from each alternative option. Moreover, the participation of higher number of interviewees/evaluators could be acceptable and, thus, generate safer outcomes. The integration of the evaluation for multiple interviewees is achieved by multiplying each element (aij) of the one matrix with the same element (aij) of the other matrices and calculating the n^{th} root of the product, where n is the number of matrices/evaluators (Ssebuggwawo et al, 2010).

It was estimated that the construction of a dry port that could undertake the majority of freight port operations is the most suitable option in terms of the criteria selected. This lays on the fact that port location is a very crucial criterion for determining the port location. A set of reasons are subject to this criterion: geostrategic location, port competition, technical and geographic issues, geomorphological features, spatial development potential and inner port spatial layout, flexibility, etc. Furthermore, there are great opportunities for more efficient rearrangement of superstructure and equipment. Better handling of cargo demand is then feasible in response to given supply characteristics.

Finally, as a step further, in order to capture the impacts of different management structures at a wider scale and diverse decision-making models on port performance, more management structures should be studied to build better correspondence between management structures and existing decision-making models. An investigation of such practices around a world could depict the relationships between management structures and decision-making models, identifying global patterns of pairs. Then, a set of performance indicators (turnover, throughput, etc.) could indicate which of these pairs produce the greater positive impacts, composing the puzzle of the most impacted management structures. With respect on the green concerns, the evaluation indicators for performance measurement could reflect environmental and energy impacts like GHG emissions, energy consumption, energy production, air emissions, intermodality rates, etc.

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ROAD TRAFFIC MEASUREMENT AND RELATED DATA FUSION METHODOLOGY FOR TRAFFIC ESTIMATION

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The knowledge of road traffic parameters is of crucial importance to ensure state-of-the-art traffic services either in public or private transport. In our days, a plethora of road traffic data are continuously collected producing historical and real-time traffic information as well. The available information, however, arrive from inhomogeneous sensor systems. Therefore, a data fusion methodology is proposed based on Switching Kalman Filter. The concept enables efficient travel time estimation for urban road traffic network. On the other hand, the method may contribute to a better macroscopic traffic modelling.

Keywords: Road Traffic Estimation, Data fusion, Switching Kalman Filter

1. Introduction

Planning schedules of urban bus services or the control of signalized junctions can be based on the knowledge of relevant traffic data. In possession of real-time traffic information, a wide range of new traffic services can be introduced, e.g. route planning for private travellers, energy-efficient vehicle control or optimal control of the whole traffic network. However, completely coherent information of the traffic state cannot be provided only by different types of sensor data that are analysed separately. This way network parameters, such as volume, density, travel time or origin-destination (OD) data cannot be determined within the whole traffic network. Covering the whole network by sensors would be the easiest method for gathering data about its traffic state. At the same time, this is only a theoretic solution, since installation and maintenance of required sensors would be extremely expensive. Therefore, a cost-efficient method is necessary to realize a cost efficient traffic state estimation based on rarely located sensors producing different types of data. Certainly, developing an algorithm that meets these requirements has several difficulties caused by inhomogeneous data types, e.g. different semantics, difference in time and location and data dropout. Considering all of these factors, the purpose of this article is the evaluation of state-of-the-art measurement data in order to fuse them. The basic idea is that the fusion of information pieces produced by different types of sensors can result in better and more efficient traffic services and systems compared to those techniques that deal with different types of sensors separately.

In the last few decades, information technology has developed rapidly; several new technologies have been introduced. Some of them are just in their beginning steps. Mobile phones (that are used by nearly all adult citizens), widespread and free smartphone applications, fleet management systems (on public transport and private vehicles as well) and several other techniques make it possible to realize a state-of-the-art and cost-efficient service.

2. Measurement techniques and their features

Measurement systems applicable to road traffic data collection can be divided into two parts: traditional and alternative techniques. Traditional techniques are sensor technologies that have been developed to measure road traffic parameters. These devices are e.g. loop-detector, magnetic detector and camera. Unlike the previous ones, alternative technologies have not been originally developed to measure road traffic parameters, even though they can provide these types of information, e.g. fleet management systems, cellular and GPS data of mobile telephones, etc. The features of different measurement types are described in this section.

2.1. Traditional road traffic measurement technologies

Traditional road traffic sensors are directly planned for accurate traffic data measurement. Basically, cross sectional measurements can be done on the traffic road network (Ludvig et al., 2012). Therefore, time dependent parameters can be obtained. These are time occupancy, time headway, volume and time mean speed. By using a single detector, time mean speed can only be estimated (by calculating with a mean vehicle length). If more detectors are placed after each other within a short distance (usually on motorways), time mean speed can be measured, not just estimated, therefore the results are more precise. Even though video image processing systems are quite developed, these devices usually operate by virtual loop-detectors. The advantage of this method is that the number and size of placed virtual loop-detectors can be freely set. Therefore, some spatial parameters such as spatial occupancy and density can be calculated.

In general, well-performing measurement systems can be built up by using traditional sensors (after adequate calibration and smoothing) for continuous measurement. The drawbacks are the high maintenance and installation costs that make it unrealistic to set up a system covering all important roads of a town. Another bound is that measurements take place only on separated cross sections. In other words, traditional sensors are not capable of measurements that cover a large area, e.g. OD data or travel time data cannot be obtained by them.

2.2. Alternative road traffic measurement technologies

Alternative sensor technology has become a real option for traffic parameter estimation due to IT developments of the last few years (Vlahogianni et al., 2014). Nowadays, numerous historic or real-time databases exist that have relevant information for road traffic parameter estimation although they have not been directly generated for traffic estimation purposes. Even though these data are not available yet for business or organizational reasons, they might be well applied for traffic control or service purposes. Expectedly, these types of data will be available soon.

One of the most common data types is the GPS data of vehicles that are part of a fleet management system. These information make real-time monitoring possible. During the operation of Floating Car Data (FCD) systems, an on-board unit provides data of the vehicle, e.g. actual speed, position or other information which are important basically for the operator, such as the fuel consumption. From these traffic data travel times, OD and route information can be estimated accurately. FCD are collected in numerous systems day-by-day either in private or public sector. In private sector usually taxis and delivery trucks apply fleet management. The system that operates in Berlin is a relevant example (Gühnemann and Scäfer, 2004). The traffic control centre is provided by real-time taxi GPS data from each vehicle in every less than 2 minutes. An example for the systems of public sector is the Hungarian 'FUTÁR' project being developed for public transportation of Budapest. Another system, operating in London, is worth to mention in which it is possible to follow real-time data for private users as well (www.tfl.gov.uk).

Another way of estimation is using Floating Mobile Data (FMD) information that contains position data of traveling mobile phones. FMD can be divided into 2 classes: client-side and server-side information systems. Client-side FMD is collected from applications typically running on smartphones for which users get traffic information in exchange. A well-known example is the Traffic application of the Google Map. The sources of data are GPS information of fleet management companies and mobile data of private smartphone users. This service does not provide exact speed values, just determines a speed category that is converted into a colour code displayed on a map for certain links (see Fig. 1).

Figure 1. Google Map screenshot in Budapest

The other way of gathering FMD information is using server-side technologies. The basis of this method is also the observation of travelling mobile phones, but only at the operator-side. If a mobile phone changes its location, it generates different types of signals according to the operation principles of radiofrequency-based telecommunication. These signals can be also applied as input data for location-based services (Küpper, 2005). This topic, among its significant research potential in other fields, is a really important way to exploit the application of network mobile phone data for road traffic observation and management. The most considerable advantage of network data is their quantity, since nearly everyone has a mobile phone. All of the cellular signals generated by users are automatically observed by the operator through base stations. Therefore mobile phones can be treated as detectors that do not require additional development of the infrastructure. Nevertheless, processing these rough data requires special algorithms (Tettamanti and Varga, 2014). The most important advantage of server-side FMD is the measurement capability on the whole network, e.g. estimation of OD matrices. Furthermore, the estimation of velocity is also possible only by using network mobile phone data (without GPS data) Nokia Solutions and Networks OY et al., 2014).

Bluetooth-based vehicle detection is another radiofrequency-based technology that is already applied in a few cities (Quing, 2011). The system is able to estimate traffic parameters by following unique identifiers (e.g. MAC address) of wireless devices situated in vehicles.

2.3. Features of different measurement technologies

Beside traditional measurement techniques, even more efficient alternative ones are available for traffic parameter estimation, especially for OD matrix estimation and travel time monitoring. All the same, it is impossible to precisely estimate traffic volume on a link based on only measured speed data. Moreover, accurate cross sectional measurements cannot be used for precise estimation of network data.

So far, only the main differences have been revealed, but there are several other features by which sensor technologies can be differentiated. Tables 1, 2 and 3 show the most important factors that have to be taken into account during application (even by using more methods simultaneously).

Table 1. Features of traditional cross sectional sensors

Measured and calculated parameters	volume
	time occupancy
	velocity
	time headway
Cycle time	optional
Technical advantages	reliability of measurements
	availability
Drawbacks	high installation and maintenance costs
	not capable to cover whole networks due to high costs
	not capable to extend measurements (OD matrix, travel times routes)
	frequent breakdowns

Table 2. Features of FCD and client-side FMD sensors

Measured and calculated parameters	position with timestamp
	velocity
	travel time
	route
	OD information
Cycle time	system-dependent
Technical advantages	reliability of measurements
	no installation and maintenance costs, data can be purchased as a service
Drawbacks	available FCD information are not necessarily representative because of the quantity (FCD vehicle are not everywhere at every time)
	estimating the traffic state of a whole network requires data of more fleets
	not capable to calculate traffic volume data
	limited application of data from taxis and buses moving in bus lanes

Table 3. Features of server-side FMD sensors

Measured and calculated parameters	position with cell-identifier and timestamp
	travel time
	route
	OD information
Cycle time	optional
Technical advantages	available FCD information are representative because of the quantity (almost every traveler has a mobile phone)
	capable to estimate the OD matrix of the whole network
	no installation and maintenance costs, data can be purchased as a service
Drawbacks	route information can only be estimated
	travel time data are inaccurate for short trips because locations of handovers have a standard deviation, but during longer trips the error becomes smaller
	in non-urban regions the estimation is not as accurate due to bigger cell sizes
	data generated by travelers using public and private transport have to be separated by smoothing from a database containing all incoming data

Table 4 gives a short review of traffic data that can be measured or estimated by sensor technologies.

Table 4. Classification of traffic data

Measurement	**Event based**	**Aggregated**
Cross sectional	current velocity, occupancy, time headway	time mean speed, volume, time mean headway
Spatial	travel time, mean velocity, position with timestamp, vehicle trajectory	space mean speed, density, OD matrix, mean travel time

3. Integrated use of different measurement systems

The advantages and disadvantages of different sensors have been described in Section 2. The purpose of combined sensor technologies is based on the opportunity that fusion of different data types results in a better outcome than using only one type of sensor data.

3.1. Data fusion

Data fusion is not a specific technique, just an object of making an integrated database of different types of information. (Mitchell, 2007) defines data fusion as follows: 'The theory, techniques and tools which are used for combining sensor data, or data derived from sensory data, into a common representational format. In performing sensor fusion our aim is to improve the quality of the information, so that it is, in some sense, better than would be possible if the data sources were used individually.'

Certainly, data fusion is not always necessary. If a perfect information source existed, there would be no need to use this technique. Using data fusion techniques may have the following advantages (Bachmann, 2011), (Klein and Mills, 2006), (Ng, 2003):

- Reliability/Robustness/Redundancy: 'The system fusing several sources of data has a higher fault-tolerance.'
- Accuracy/Certainty: 'The combination of several different kinds of sensors can produce more accurate information.'
- Completeness/Coverage/Complementarity: 'More data sources will provide extended coverage of information on an observed object or state.'
- Cost effectiveness: 'If using sensors on the whole network, especially on a traffic network, was too expensive, applying data fusion techniques would be a profitable alternative.'
- Representation: 'Sensor fusion is necessary to combine information and clearly present the best interpretation of the sensor data.'
- Timeliness: 'More timely information may be provided by multiple sensors.'

3.2. The purpose of data fusion in transportation

Measurement, information and control systems cannot reach maximal effectiveness if they work separately, because none of them has information on the entire network. If rough data is processed in an integrated way, the information about the network is more precise that results in the fact that all subsystems work in a more efficient way. This means that data fusion can help all intelligent transportation subsystems to improve (Anand et al., 2013), (El Faouzi et al., 2011). The functions of these subsystems are usually measurement, estimation, forecasting, control and information collecting or providing (Quing, 2011).

- Measurement systems: Data fusion techniques make it possible to make a standard platform for data having different semantics and syntax. The next step is the development of estimating and data completing algorithms that can also analyze those parts of the network from which in a current time step no sensor information have been collected.
- Information systems: Providing information for travelers and drivers is a basic criterion of transportation nowadays. Modern navigation systems are provided with traffic and road state information. Certainly, the knowledge of the entire network state is an advantage.
- Estimation and forecast: The knowledge of the present state of the network is crucial for traffic control. The result can be even better if not only is the present state of the network known, but the future state can also be forecast (Guo et al., 2013).
- Network traffic control: Besides providing information for travelers, improving the efficiency of navigation and incident detection, the most important factor of traffic data fusion is providing data for traffic network control. In this case the state of traffic can be optimized based on traffic volume and OD data.

Certainly, these systems do not always operate separately. Moreover, they cannot often be separated, since the systems support or complete each other in many cases.

3.3. Data fusion methods in road transportation

Many articles have been written recently that have introduced different data fusion techniques. The purpose of this section is to give a short review of them.

The most common used data fusion technique among researchers is the Kalman Filter (Wardrop, 1952), (Welch and Bishop, 1995) with its variants (e.g. the extended Kalman Filter). The first time it was applied for road traffic was in 1972 by Szeto and Gazis (Szeto and Gazis, 1972). The basic theory of this research is that most analytic traffic models can be generated by state space representation. One of these solutions is described in (Chu et al., 2005) claiming that even only measuring by more loop-detectors can meet the requirements of sensor fusion. All the same, some other researches use inhomogeneous data sources to improve estimation quality. In (Herrera and Bayern, 2007) the traditional cross sectional measurement is combined with moving sensors that actually means following GPS based trajectories of some specific vehicles. In this case from GPS data of moving vehicles, by using the conservation equation and the macroscopic model, density and speed of a specific location can be determined. That has a same representation as the cross sectional measurements.

The most considerable advantage of the application of different digital filters is the fact that estimation can be done in an iterative way, whereas capacity requirements of computation are low. As the capacity limit of computations had extremely increased, new real-time solutions became available, which is the reason for optimizing techniques being widespread. The target is to compose an objective function for a specific traffic data, e.g. for travel time. Constraints are given by traffic models and the data themselves. This method is used in (Böker and Lunze, 2002) in which cross sectional measurements vehicle measurements and the traffic model are combined. These give constraints for linear programming equations of which the solutions are the estimated minimum or maximum travel times.

Another way of traffic parameter estimation with low computing capacity is represented by interpolation techniques. These are similar to convolution image filtering techniques. A smoothing convolutional filter technique was introduced in (Treiber and Helbing, 2002) by using the interpolation technique in order to fuse stationary data (loop-detectors) and non-stationary (FCD) measurements.

Previous techniques exploit the relationship between the measured data and the traffic model. During using data fusion techniques, by weighting the traffic model and the measured data, a balance can be set among them. Another method is suggested by (Quing, 2011) using the principle of data-data consistency. It calibrates one or two pieces of measured data with each other by using only non-linear models. Smoothing the noise of loop-detector data by comparison with noiseless FCD based travel time data is a typical example for this method.

4. A data fusion method for urban road traffic

Data fusion is one of the most researched topics in transportation due to the fast improvement of information technology. Techniques introduced in scientific articles are usually to reconstruct the state of motorway traffic by using cross sectional measurements (e.g. loop-detector) and FCD/FMD (e.g. Claudel and Bayern, 2008). The opportunity of using cell information of mobile phone networks in transportation is an unexploited research field at present. Another unexploited research field is the construction of an integrated data model that can estimate the traffic state for an entire urban network by using all sensor measurements. Thus, there is a great potential in these research fields. Therefore, in the following part of the article the basis of an integrated data fusion model for urban traffic data are described. This research has been invoked by the 'Smarter Transport' project (TÁMOP-4.2.2.C-11/1/KONV-2012-0012) of which the purpose is the development of a traffic data collecting technology based on combined measurement systems.

4.1. Problems of the urban network

The application of a data fusion method on an urban network has several difficulties caused by the features of urban traffic. An obvious problem is the complicated road network, so route reproduction from server-side FMD sensor data is much more difficult compared to motorways.

Another difficulty is the effect of signalized traffic control that has a strong influence on traffic flow. Traffic on motorways is described by macroscopic fluid models that have a clear principle. In contrast, urban models are either rough or even if they are detailed, macroscopic models often cannot be applied because of the high number of necessary measurements and computation.

A further problem is that only loop-detector is capable of direct precise traffic volume measurement, all of the other sensors are not. The OD data of server-side FMD can be applied only for a rough estimation, e.g. estimation of aggregated zone-to-zone travel data.

Considering the problems, the purpose of this research was to find an approach that does not use complicated models and only tries to precisely estimate the traffic state of specific urban roads by the fusion of different types of sensor data. Since FMD/FCD measurements represent travel time well and it can also be estimated from loop-detector measurements, the unknown parameter of the integrated data fusion model is travel time.

4.2. Kalman Filter based sensor fusion

The proposed data fusion methodology is based on the method of the Kalman Filter estimation often used by traffic engineers. This technique is a recursive method for linear filtering of discrete data (Welch and Bishop, 1995). The method makes it possible to precisely estimate the state of a dynamic system, even if its exact nature is unknown.

The linear Kalman Filter can be applied if the state space representation of the system is determined. The state of a discrete, sampled, time-invariant process is described with a linear difference equation

$$x(k+1) = Ax(k) + Bu(k) + w(k), \tag{1}$$

where $x(k) \in \mathbb{R}^n$ is the state vector, $u(k) \in \mathbb{R}^m$ is the control input vector, $w(k)$ is the process noise, $A \in \mathbb{R}^{n \times n}$ and $B \in \mathbb{R}^{n \times m}$ coefficient matrices and $k = 1, 2, \ldots$ is the discrete timestep. $x(k+1)$ describes the state change in the $[kT, (k+1)T]$ time interval, where T is the sampling time period. The measurement equation of the system generally is:

$$y(k) = Cx(k) + v(k), \tag{2}$$

where $y(k) \in \mathbb{R}^p$ is the vector containing measurement data, $v(k)$ is the process noise and $C \in \mathbb{R}^{p \times n}$ is the measurement matrix. The filter can be applied if process noise$w(k)$ and measurement noise $v(k)$ are assumed to be zero mean Gaussian white noise, so $E\{w(k)\} = 0$ and $E\{v(k)\} = 0$. The covariance matrices are assumed to be

$$Q = E\{w(k)w(k)^T\}, \tag{3}$$

$$R = E\{v(k)v(k)^T\}. \tag{4}$$

The Kalman Filter estimates the state of the next time step based on the state of the current time step but the estimation is refined in the next time step considering the measurement result of the period. Furthermore, it estimates system covariance that is also refined by the result of the latest measurement. It means that the filter has a two-phase operation: prediction and correction. Let $\hat{x}^-(k)$ be the *a priori* state estimate at step k and $\hat{x}(k)$ the *a posteriori* state estimate at step k. Now, the *a priori* and *a posteriori* estimate errors are defined which make it possible to determine the *a priori* and *a posteriori* estimate covariance $P^{-}(k)$ and $P(k)$ which represent the square of the estimated errors. The two-phase estimation algorithm is shown in Fig. 2.

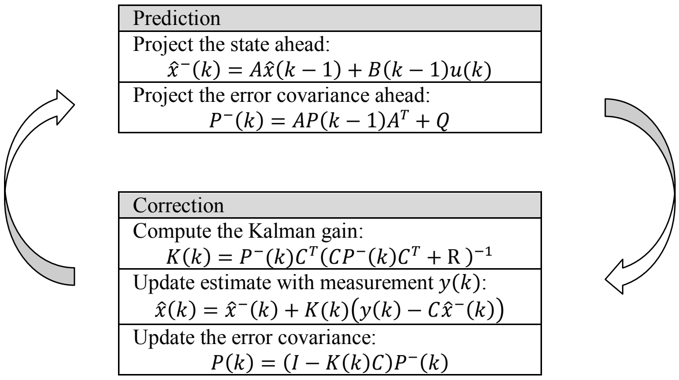

Figure 2. The two-phase Kalman Filter algorithm

The Kalman Filter introduced so far can be directly applied for sensor fusion. The only condition is that correlation among different measurement noises is not permitted.

If the results of sensor measurements are temporarily available, the state space representation of travel time estimation is:

$$x(k+1) = x(k) + w(k), \tag{5}$$

$$y(k) = Cx(k) + v(k). \tag{6}$$

where (5) describes the system dynamics based on the random walk model, that is $A = I$ and $B = 0$. The reason for it is the unknown changing behaviour of travel time, therefore it is considered as a random process. Since in this example travel time is estimated only for a single link, $x(k)$ and $w(k)$ are scalar variables. At the same time, $y(k)$ in the measurement equation describes a system of equations. The dimension of $y(k)$ equals the number of sensors. For example, if 2 different sensors (e.g. FCD and FMD) are involved measuring travel time:

$$\begin{bmatrix} y_1(k) \\ y_2(k) \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \end{bmatrix} x(k) + \begin{bmatrix} v_1(k) \\ v_2(k) \end{bmatrix}. \tag{7}$$

The Kalman Filter can estimate state directly from measurements $y_1(k)$ and $y_2(k)$ that are automatically weighed according to their covariance. It is followed by their fusion that results in an integrated state estimation. The more precisely the standard deviations $v_1(k) = \sigma_1$ and $v_2(k) = \sigma_2$ are known, the more precise the operation is. Standard deviations can be determined in an empirical way. In the example they can be calculated by the standard deviations of general FMD and FCD measurements.

4.3. Sensor fusion with the Switching Kalman Filter

The sensor fusion methodology introduced in the previous subsection can be applied easily and efficiently if synchronized measurement data can be gathered at each measurement period. This condition, however, is not always fulfilled even on urban roads with heavy traffic. A possible solution for the problem is the application of the switching system state space representation (Liberzon, 2003). In this case, the system is described with more (but not infinite) space state representations that practically mean different operational modes. Moreover, different Kalman Filters can be constructed for different operational modes. The system changes its operational modes followed by the Kalman Filter switching into another mode as a reaction for the change of external effects (Böker and Lunze, 2002). The switching, discrete and linear state space representation based on (1) and (2):

$$x(k+1) = A_{\rho(k)}x(k) + B_{\rho(k)}u_{\rho(k)}(k) + w_{\rho(k)}(k), \tag{8}$$

$$y_{\rho(k)}(k) = C_{\rho(k)}x(k) + v_{\rho(k)}(k), \tag{9}$$

$$\rho(k) \in S = \{1, 2, \dots, s\}, \tag{10}$$

where $\rho(k)$ is the discrete switching signal that refers to the operational mode of the system in time step kT and determines the values of matrices A, B, C and signals u, w, v. Considering its temporal states, $\rho(k)$ can be rule-based or a random sequence signal.

The operation of the Switching Kalman Filter is based on the algorithm shown in Fig. 2, the difference is that in this case the algorithm is always actualized for the current $\rho(k)$ system mode. The filter contains intermediate values $\hat{x}^-(k)$ and $P^-(k)$, even if the current mode is different from the previous one, i.e. $\rho(k) \neq \rho(k-1)$. The modified estimation algorithm is shown in Fig. 3.

Prediction
$\hat{x}^-(k) = A_{\rho(k)}\hat{x}(k-1) + B_{\rho(k)}(k-1)u_{\rho(k)}$
$P^-(k) = A_{\rho(k)}P(k-1)A^T_{\rho(k)} + Q_{\rho(k)}$

Correction
$K(k) = P^-(k)C^T_{\rho(k)}\left(C_{\rho(k)}P^-(k)C^T_{\rho(k)} + \mathrm{R}_{\rho(k)}\right)^{-1}$
$\hat{x}(k) = \hat{x}^-(k) + K(k)\left(y_{\rho(k)}(k) - C_{\rho(k)}\hat{x}^-(k)\right)$
$P(k) = \left(I - K(k)C_{\rho(k)}\right)P^-(k)$

Figure 3. The two-phase algorithm of the Switching Kalman Filter

4.4. Travel time estimation on urban links by sensor fusion

Using the Switching Kalman Filter is a solution for the problem of inhomogeneous sensors producing inhomogeneous data during road traffic measurements. Therefore, the continuously changing number of sensors does not cause any difficulties, at the same time the benefits of Kalman Filter can be exploited for data fusion. The purpose of this subsection is to describe a data fusion methodology for the estimation of travel time on any urban link, exploiting the opportunities.

The Switching Kalman Filter can be applied if the system can be observed, that is:

$$rank \begin{bmatrix} C_{\rho(k)} \\ C_{\rho(k)}\, A_{\rho(k)} \\ \vdots \\ C_{\rho(k)}\, A^{n-1}_{\rho(k)} \end{bmatrix} = n. \tag{11}$$

If no measurement data is available for a current time step, this requirement is not met. If the data of at least one sensor is at service, the requirement is met. Considering the frequency of sensor measurements and the number of sensors, only spatially fixed sensors are able to measure continuously by all means. As a consequence, at least one cross sectional loop-detector is required. In urban networks this might be usually available. Any other sensors (e.g. FCD, FMD, Bluetooth, etc.) are considered as potential devices in the network, whereas their permanent operation is not a requirement. The main drawback of this approach is measuring travel times by cross sectional detectors, which obviously cannot be done directly. Therefore simulations have been done in a modelled environment in which it is possible to determine the mean travel time on a link within typical traffic volume conditions. The result can be either a function ($T = f(Q)$) or a simple determination of volume scales. In that case, as an example, a mean travel time can be determined for 0-200 veh/h, another one for 201-500 veh/h and so on. Travel times determined for links within different volume conditions during simulations can be applied as measurement results. For a volume data measured by a real detector, a simulation-based mean travel time can be assigned.

The applied switching system based on (5) and (6):

$$x(k+1) = x(k) + w(k), \tag{12}$$

$$y_{\rho(k)}(k) = C_{\rho(k)}x(k) + v_{\rho(k)}(k), \tag{13}$$

$$\rho(k) \in S = \{1, 2, 3, 4\}, \tag{14}$$

where state variable $x(k)$ represents mean travel time of a specific link. Switching signal $\rho(k)$ has an effect only on the measurement equation. Set S contains four possible different measurement combinations using 3 different sensor types (loop-detector, FMD, FCD). The combinations are shown in Table 5.

Table 5. The different measurement configurations

$\boldsymbol{\rho(k)}$	$\boldsymbol{y_{\rho(k)}(k)}$	$\boldsymbol{C_{\rho(k)}}$	$\boldsymbol{v_{\rho(k)}(k)}$
1	$\begin{bmatrix} T_1^{loop} \end{bmatrix}$	$[1]$	$[\sigma_1]$
2	$\begin{bmatrix} T_1^{loop} \\ T_2^{FCD} \end{bmatrix}$	$\begin{bmatrix} 1 \\ 1 \end{bmatrix}$	$\begin{bmatrix} \sigma_1 \\ \sigma_2 \end{bmatrix}$
3	$\begin{bmatrix} T_1^{loop} \\ T_3^{FMD} \end{bmatrix}$	$\begin{bmatrix} 1 \\ 1 \end{bmatrix}$	$\begin{bmatrix} \sigma_1 \\ \sigma_3 \end{bmatrix}$
4	$\begin{bmatrix} T_1^{loop} \\ T_2^{FCD} \\ T_3^{FMD} \end{bmatrix}$	$\begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}$	$\begin{bmatrix} \sigma_1 \\ \sigma_2 \\ \sigma_3 \end{bmatrix}$

Measurement vector $y_{\rho(k)}(k)$ contains the combination of travel times measured by sensors of different types. Note that the first element of $C_{\rho(k)}$ is always 1, which represents permanent loop-detector measurements, hence satisfies Eq. (11). The second and third element can be either 1 or 0. If no FCD and/or FMD have been detected within the current time step, the value is 0, else 1. The Switching Kalman Filter switches according to the signal $\rho(k)$ (see Table 5) that is a known value.

For a precise estimation measurement noise $v_{\rho(k)}(k)$ is assumed to be known. This can be determined by the standard deviation of measurements. The values of $v_{\rho(k)}(k)$ continuously change, since the standard deviation of a sensor is not temporary like FCD based travel time if it is a result of interpolation. The standard deviation of loop-detector data can be calculated by the evaluation of simulation runs. Standard deviation of travel times measured by FCD and FMD techniques can change even within the current measurement. Travel times calculated by the cross sectional detector have the highest standard deviation. The noise of FCD/FMD measurements is much lower, which results in more precise estimations. As a consequence, measurement estimation is expected to be much reliable during the rush hours (when FCD/FMD are probably available) and less out of them. However, during these periods travel time data can be calculated from static databases, since the effect of traffic is low. The described data fusion estimation method is shown in Fig. 4.

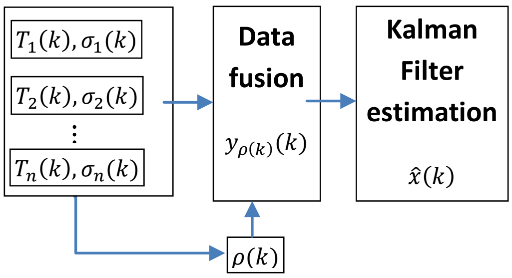

Figure 4. The sensor fusion method for the estimation of mean travel times on urban links

4.5. Sensor fusion for network traffic estimation

Information produced by the method introduced in the last subsection would be useful for travelers. All the same, these estimation data can be applied for the entire network as well. Therefore they can be used for the refinement of macroscopic traffic estimation. In a previous article of the authors (Tettamanti and Varga, 2014), route assignment has been developed by using travel time data. If either a predetermined (using historical data) or a real-time (using cellular data) estimated OD matrix is available, traffic can be assigned in a traditional way (Wardrop, 1952). Practically, the assignment creates a traffic model estimating traffic volume on the network links. This method can be improved by involving travel time results of the data fusion methodology. Hereby, a dynamic traffic assignment can be done applying the real-time traffic data.

The main point of the method is that performance functions (t_a) of links are limited by the measured travel time data (Tettamanti and Varga, 2014). Therefore optimizing traffic assignment has another bound:

$$t_a^m(1-\Delta_a) \le t_a \le t_a^m(1+\Delta_a), \tag{15}$$

where t_a^m represents the measured mean travel time for a link and Δ_a is an uncertainty factor that can be empirically calibrated for example by the standard deviation of the measurement.

4.6. Difficulties of real-world application

The opportunities of the introduced measurement methodologies are described in the previous sections. In this subsection the difficulties of real-world application are analysed.

The biggest uncertainty of server-side measurements is the error of mobile phone location. Location area updates and handovers are not absolutely deterministic; therefore the location of such events can have a standard deviation up to hundreds of meters. Thus, these types of measurement techniques are worth using for longer trips, where the degree of standard deviation compared to the trip length is low.

In general, another serious problem of FMD measurements is that the travel mode is unknown; therefore pre-filtering is required in order to differentiate motorists from pedestrians.

However, FCD are definitely vehicle data, some vehicle classes have special ‘disturbing’ features. For example taxis and buses can use bus lanes, the velocity of bigger vehicles is lower, delivery vehicles often stop on the road for loading and unloading, etc.

Considering these factors, it is obvious that the method introduced in this article has many factors to be solved but none of them is impossible from engineering aspect.

5. Conclusions

In this article the applied methods of traffic measurements and their classification including some of the sensor technologies have been revised. After that, a data estimation concept has been introduced for urban network traffic. The proposed methodology using sensor fusion technology is based on the Switching Kalman Filter that makes the efficient integrated application of very inhomogeneous types of sensor data possible. Moreover, the method has another opportunity, since using data provided by data fusion can improve real-time macroscopic traffic modelling.

The future purpose of the research is the validation of the introduced methodology by simulation runs and real data. The research is related to a Hungarian town, Győr. Accordingly, using sensor data from the network of the town is planned.

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A TRAVELLER INFORMATION SYSTEM: MINIMISATION OF THE NUMBER OF GRAPHS' NODES INVOLVED WHEN PROCESSING ROUTE REQUESTS

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The number of people using public transport is continuously increasing. Transport companies want to fulfil travellers' expectations wherever possible. However, the great number of public transport companies operating in the same area can sometimes confuse travellers as to which route they should take and how to obtain the information relative to their journey. In this paper we suggest integrating several traveller information systems from different companies into the same multimodal information system, offering companies the choice not to share their data. This encourages them to join the system. Additionally, we have minimised the number of nodes involved when processing travellers' requests in order to simplify the calculation process. To put our plan into action, we have opted for a multi-agent system coupled with the Voronoi decomposition for managing the network.

Keywords: Information system, traveller information, multi-agent systems, Voronoi decomposition

1. Introduction

The public transport sector is undergoing rapid expansion. Companies are increasingly innovative in how they meet travellers' needs. Each company has its own stops, modes of transport, and pathfinding algorithms, and interacts with the traveller through its information system, often via the internet.

A company's traveller information system (TIS) allows travellers to calculate their route and obtain the information they require (Adler and Blue, 1998). They can use two types of network: unimodal or multimodal. The first type takes a single mode of transport into account, whilst the second type takes at least two into consideration (Vasco et al., 2013). An effective TIS even considers walking as a possible mode of transport. With the competition and diversity that the transport sector is undergoing, travellers must have a sound knowledge of routes, websites and interchange stations served by each company in order to obtain the multimodal information desired. In the case of a long distance journey, it is very probable that travellers may have to use numerous operators' information systems in order to find the information they require.

To avoid travellers' manual searches, and to guarantee their comfort, we propose in this paper integrating multiple traveller information systems into the same multimodal information system. It is important to note that usually, a company must share all of its information, data and algorithms to belong to a multimodal information system. However, this data can be crucial for competition and mastery of the market. The potential loss of this valuable data can dissuade companies from joining a system. To remove this obstacle and encourage transport companies to join a multimodal information system, we suggest an architecture in which every company retains its autonomy from the point of view of data management. When the proposed system receives a request from a traveller, it breaks it down into multiple sub-requests and interrogates the companies selected for the desired route in order to provide sub-responses. The fusion of these sub-responses forms the final information offered to the traveller.

During bibliographic research in this field (Schulz, 2005; Zidi, 2006; Kamoun, 2007; Zgaya, 2007; Pajor, 2009; Zhang et al., 2012) we did not identify any project recommending a multimodal information system that integrates the information systems of different transport companies and allows the size of the search space[1] to be minimised when processing of travellers' requests. This work addresses the size of graphs when applying pathfinding algorithms. Instead of applying pathfinding algorithms to different

[1] The search space is the information search domain. In the case of transportation and route request processing, the search space represents the graphs of the companies' networks.

transport companies' graphs in their entirety, we suggest a virtual break down of the different networks according to their congestion. The decomposition is based on the Voronoi diagram (Slimani, 2011), in order to apply the pathfinding algorithms to the sub-networks. This technique has allowed us to minimise the number of nodes in graphs involved when processing route requests, which simplifies the calculations process.

The rest of the paper is organized as follows: section 2 provides an overview of the research area. Section 3 discusses the methods we have used to develop our system. In section 4 we present the results obtained following use of our approach. These results are discussed in section 5. We finish with a conclusion, including future possibilities.

2. Related Work

The first generation of traveller information systems worked to improve traffic flow by keeping motorists updated on traffic and disruptions via radio and signposts (Adler and Blue, 1998). At the end of the 1980s the city of Stockholm's timetables were computerized and gave rise to the first traveller information system (Kramers, 2014), accessed via a telephone number and using touch keys (*#). Advances in information systems and the internet, and the appearance of navigation systems such as the Global Positioning System (GPS) have contributed to developments in traveller information systems. A significant amount of research has addressed issues concerning passenger information and pathfinding algorithms. We shall list a few of them below.

In France, (Petit-Roze et al., 2004) proposed a multimodal mobility aid service, based on personalising information according to a traveller's profile. (Zidi, 2006) presented an interactive system to aid travelling under normal and heavy congestion conditions. This system aims principally to minimise travellers' waiting times. (Zgaya, 2007) suggested a multi-agent system that used genetic algorithms to search for and compose services linked to multimodal transport between several competing operators. (Kamoun, 2007) proposed a cooperative mobility information system by automating the pathfinding processes. In Germany the "DELFI" project, launched in 1996, gave rise to the first multimodal information system on the national level. The network is divided into sixteen regions and each federal state manages the networks of its own public transport companies. This requires applications to be integrated via standardised interfaces using the COBRA protocol (Danflous, 2000). (Schulz, 2005) carried out intensive research into the models of network representations and the passage from a unimodal to a multimodal network. (Pajor, 2009) undertook research on multimodal routing between intercontinental networks. The aim was to make a model of the network, apply pathfinding algorithms and finally to use optimisation techniques to accelerate the search process.

Other applications have been developed to aid multimodal mobility. In the United States, (Zhang et al., 2011; Li et al., 2010; Jariyasunant et al., 2010) presented applications to facilitate travel, taking into account real-time data. In the United Kingdom a number of multimodal information systems calculate travel from door to door, such as "Transport Direct", "Journey Plan", and "TFL" (Danflous, 2003). Switzerland possesses its own multimodal information system which is utilised at a national level, and is based on a totally centralised architecture (Danflous, 2001). In the Netherlands, the "9292ov" system allows for travel from one location to another. Initially launched using telephony, it is now accessible over the internet (Danflous, 2006). (Kumar, 2005) developed a traveller information system for journeys in the city of Hyderabad in India. Other firms such as Trapeze, Jeppesen, and Google have developed their own mobility aid products.

The cited works present a few aspects of multimodal information systems. All of these models are based on totally or partially centralised architectures. In centralised architectures, all the nodes of all public transport companies form a single network in which a pahthfinding algorithm is applied to compose the itinerary required by the traveller. In partially centralised architectures (architecture centralised by zone), the networks of transport companies which operate within the same geographic perimeters form a super-network. Communication between these super-networks allows for a response to travellers' requests. These two methods, although effective, require all the nodes within each company's graph to be systematically taken into account, including those not relevant to the request. Processing a route calculation in a centralised system implies the manipulation of all companies' graphs, even if the journey only concerns a single company. In order to remedy this problem, we have proposed breaking down different companies' networks (graphs) according to congestion. Our system has an overview of all the companies' networks and breaks them down into several zones corresponding to the Voronoi diagrams (Slimani et al., 2011), then informs the various companies about which zone each node should belong to. Upon receiving a route request, the proposed system only requests information from the relevant sub-networks of the companies concerned.

The systems cited above were concerned with processing route requests between several companies. Nevertheless, the traveller information can be of several types: information about routes, real-time information about disruptions, or other tourist information about monuments or other places that the traveller can discover whilst travelling (Zgaya, 2007). In this work we are interested in route requests and enquiries concerning tourist information.

3. Towards a Multimodal Information System

This work aims to offer a multimodal and multi-operator information system which minimise the number of nodes utilised in dealing with requests. Our system has an overview of all the companies' networks, it divides different companies' networks into multiple zones depending on the stations' congestion. Upon receiving a request, it localises the zones concerned and then searches within the transport companies' sub-networks which belong to these zones. In order to divide the general network into zones, we have adapted the Voronoi diagram to a transport network. Our system architecture makes use of a multi-agent system.

3.1. Adapting Voronoi diagram for transport

The Voronoi diagram (VD) is an interesting structure in computational geometry (Berg et al., 2008). It is the spatial solution for the nearest-neighbour problem. Given a set of N point sites S ($S=\{S_1,S_2,\ldots,S_N\}$), for each site Si, Si.x and Si.y denote the x-coordinate and y-coordinate of Si, respectively. The VD of S (VD(S)) is the subdivision of the plane into N disjoint regions/cells according to the nearest-neighbour rule: each region/cell corresponds to one site and is composed of the set of the plane‘s points that have this site as the nearest site among all sites of S (Figure 1) (Slimani, 2011). A requisite step in the Voronoi decomposition therefore is to initialise pre-selected points.

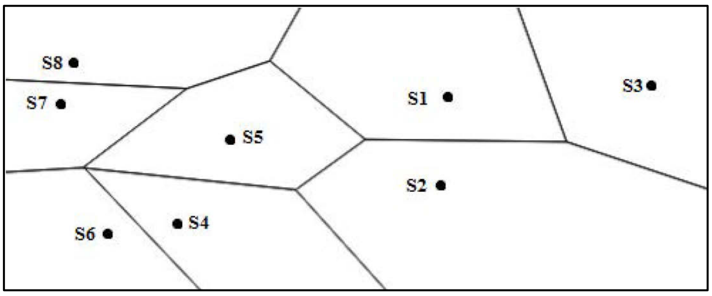

Figure 1. Voronoi diagram of eight randomly selected locations

The Voronoi diagram is applied to our problem as follows: let S be the set of all the stations of all the transport companies $S = \{S_1, S_2 ... S_n\}$. Let $S'' = \{S_1, S_2 .. S_m\}$ a subset of S, ($S'' \subset S$ and $m < n$) which represents the stations that we select according to their congestion (heavily congested stations, medium congestion stations, or uncongested station). One Voronoi cell of station S_1 ($S_1 \in S''$) is defined by the stations belonging to the set (S - S'') and closer to S_1 than to the other S" stations. The number of cells (zones) depends on the number of elements within S''. In order to calculate the distances between two stations, we have calculated the great circle distances (Gade, 2010). For this calculation we have assumed the Earth to be a perfect sphere with a diameter of 6367 km and we have used the formula presented in (Gade, 2010):

$$D(\alpha,\beta;\alpha',\beta') = 2R\arcsin\sqrt{\sin^2(\frac{\alpha'-\alpha}{2}) + \cos\alpha.\cos\alpha'.\sin^2(\frac{\beta'-\beta}{2})}$$

R is the diameter of the sphere (Diameter of the Earth ~ 63670000 metres). The latitude and longitude, in radians, of the first station are α and β respectively, and the latitude and longitude, in radians, of the second station are α' and β' respectively. A transport company's stations can then belong to numerous zones according to their congestion. The union of sub-networks of a transport company forms the totality of its network. Only a transport company's sub-networks concerned by a request are considered, and not its total network.

3.2. Our System Architecture

Multi-agent systems (MAS) divide a process between several agents. Instead of having a single programme that manages the entire system, the problem is divided and each agent has the task of resolving a sub-problem. The final solution is obtained through the interaction between different agents, referred to as distributed artificial intelligence (Ferber, 1995).

Numerous works in the transport domain have made use of multi-agent systems to achieve:

- The modelling of urban transport networks.
- The regulation of disturbances in transport networks.
- The personalisation of multimodal information.

In order to respond to passengers' enquiries and produce multimodal information, a multimodal traveller information system must access the information systems of the various companies which compose it in order to work out the final answer. It becomes the mediator between the various information systems, it must find the right sources in a distributed environment, manage the heterogeneity of the information, and present travellers with clear solutions.

Our multimodal information system is organized around five types of agents (figure 2): interface agents (IA), identifier agents (IdA), directory agents (DA), collector agents (CA), and fusion agents (FA).

Interface agents act as the interface between our system, on the one hand, and the travellers or companies who wish to enrol, on the other. The identifier agents identify a request as a route request or a request for tourist information and send an enquiry to the directory agent for the search space corresponding to the request. The directory agents have an overview of the stations and networks of all transport companies. They enrol new transport companies wishing to belong to the system, carry out a virtual break down of the network according to the Voronoi diagram, and provide the search space by selecting the companies and exchange stations concerned. The collector agents are mobile agents which move through the search space to collect the necessary information from each company concerned by the request. Finally, the fusion agents compose the responses according to users' profiles.

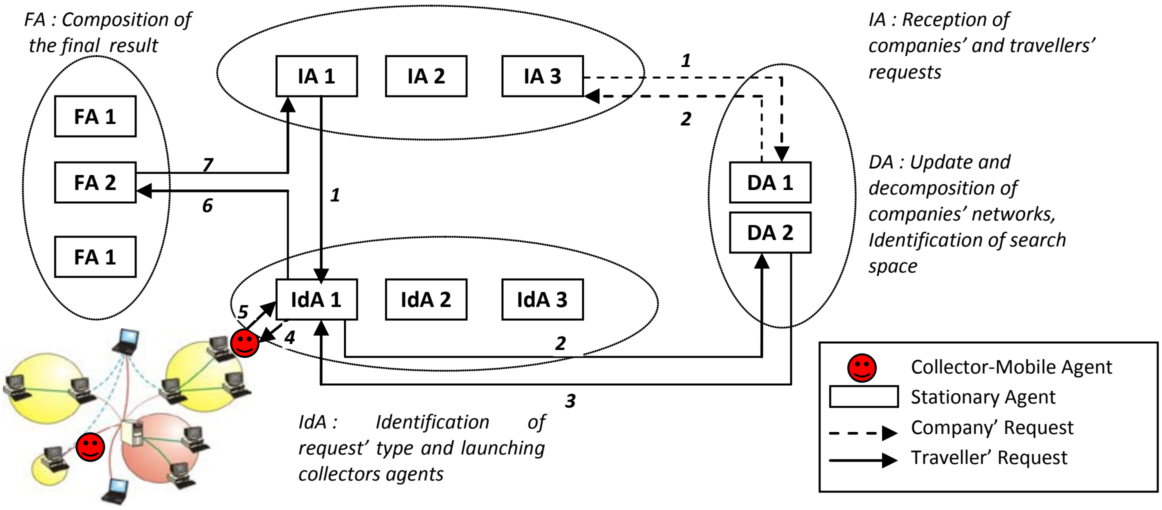

Figure 2. Architecture of our system

Interface Agent

The interface agent handles two different situations:

- Either it receives a request from a transport company that wants to integrate the system. Then it passes it onto the directory agent.
- Or it receives a request from a user searching for multimodal information. If the user submitting the request can be identified, his or her profile is extracted so that answers are processed and presented according to his or her needs. Otherwise, the user is assumed to have a standard profile and the request is submitted to the identifier agent.

Figure 3 is a diagram showing the interface agent's activities.

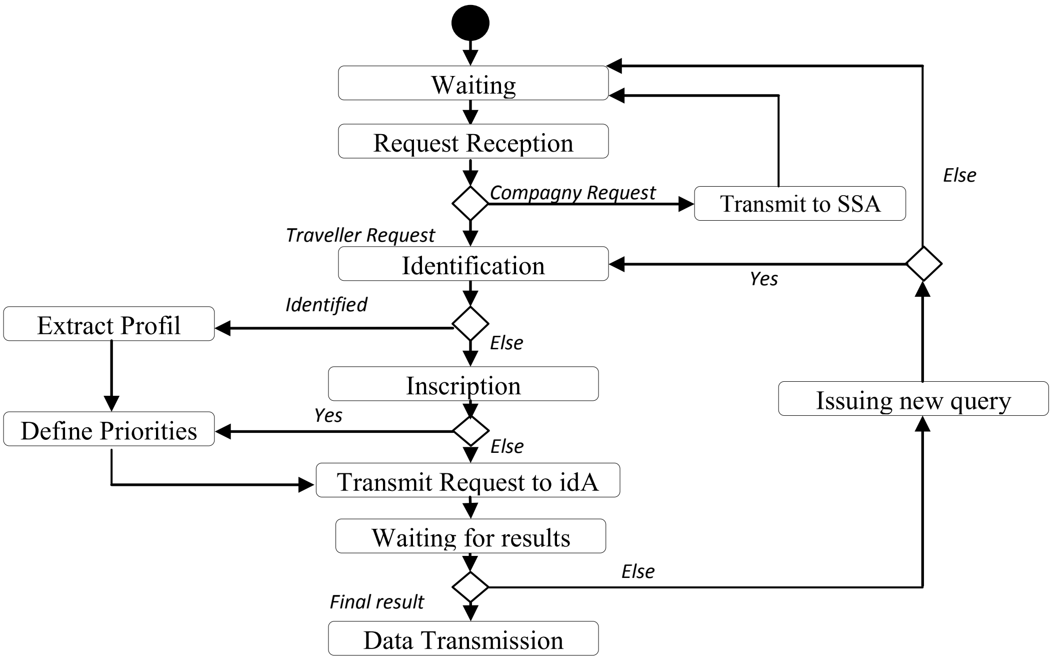

Figure 3. Activity diagram of the interface agent

Identifier Agent

The identifier agent receives requests from the interface agent. These requests can be of two sorts: either a route request, or a request for tourist information. If it is a route request, the agent determines the departure station and the arrival station and asks the directory agent for the search space. If the request is concerning tourist information, the name of a monument or square is extracted, and a request to determine the search space is sent to the directory agent. If the request is successful, the collector agent is launched to collect the required information from the different companies involved. Once the results have been obtained, it transmits them to the fusion agent. Figure 4 is a diagram showing the identifier agent's activities.

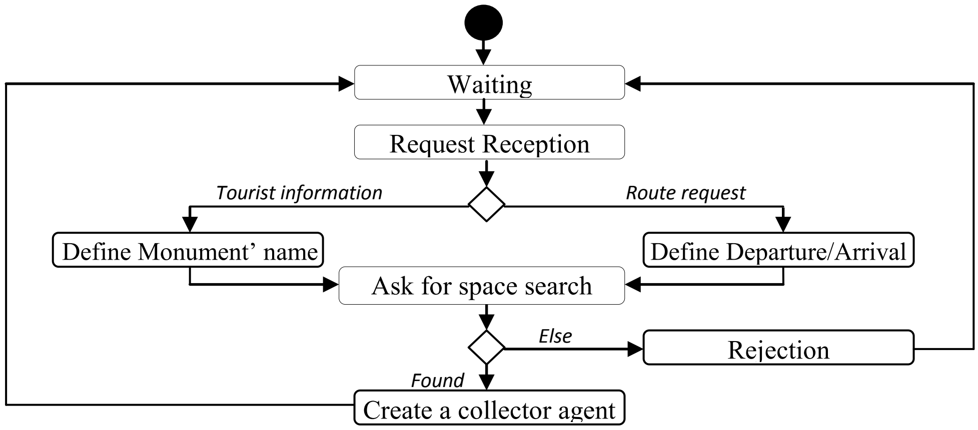

Figure 4. Activity diagram of the identifier agent

Directory Agent

The directory agent has two functions:

- It receives enrolment requests from new companies through the interface agents. Information including lines, exchange stations, and network addresses, is provided. To update the network zones, the network is broken down again using the Voronoi algorithm which is presented in section 3.3.

- It receives requests from the identifier agents concerning the search information space. Such requests are of two types:
  - The request has, as an argument, the name of a monument, a square, or a building. The directory agent localises the zone this site is designated to and the stations and stops closest to this site, using the great circle distances, which are the shortest distances between two points on a sphere, according to the formula presented in (Gade, 2010). The search space is defined by all of the companies responsible for these stations.
  - The request has, as arguments, a departure station and an arrival station. The directory agent selects the arrival and departure zones and, where necessary, the intermediary zones, and all companies involved in the request. The search space algorithm when dealing with route requests is presented in rubric 3.4.

Figure 5 is a diagram showing the directory agent's activities.

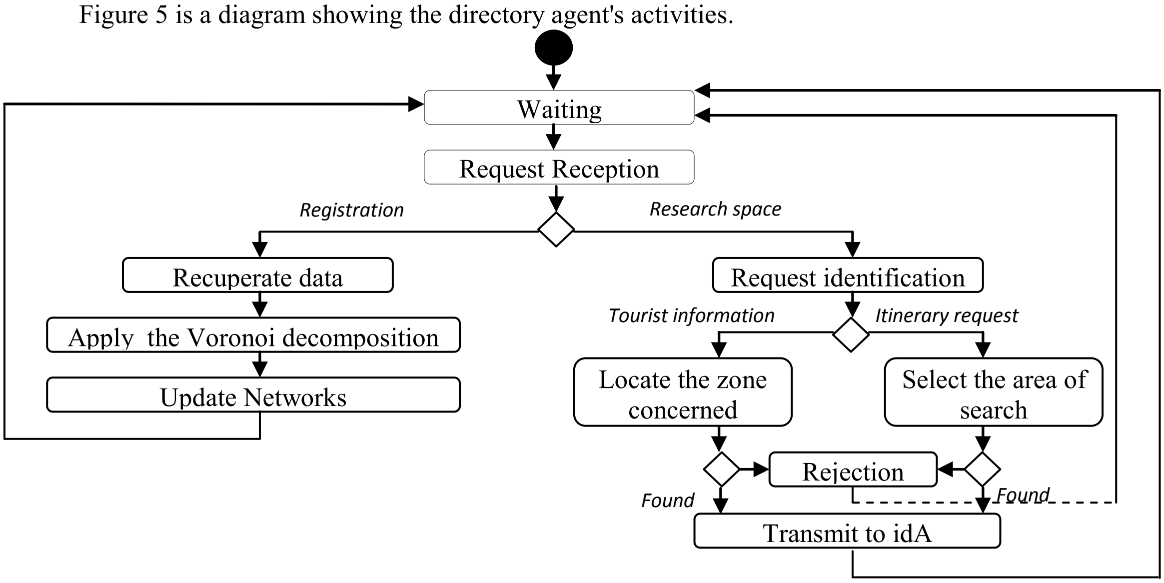

Figure 5. Activity diagram of the directory agent

Collector Agent

The collector agent is a mobile agent with the capacity to move throughout the system. It collects necessary information from each node. In our case, a node represents the information system of a company belonging to our multimodal information system. The network address and mode of communication of each company is at the collector agent's disposal. It collects the sub-answer which has been demanded of each node (company). Once all of the nodes have been visited, the collector agent returns to the host node and communicates the collected data to the fusion agent. Figure 6 is a diagram showing the collector agent’s activities.

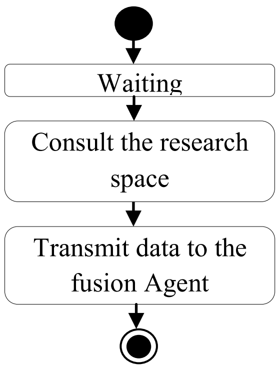

Figure 6. Activity diagram of the collector agent

Fusion Agent

The fusion agent is responsible for bringing together the collection of answers gathered by the collector agent. If the request is concerning tourist information, the reply is constant for all profiles. If the request is concerning an itinerary, the reply can vary depending on the traveller's profile. In order to better reply to travellers' expectations, we have considered two selection criteria which the user specifies at registration: age and preferences. Figure 7 is a diagram showing the fusion agent's activities.

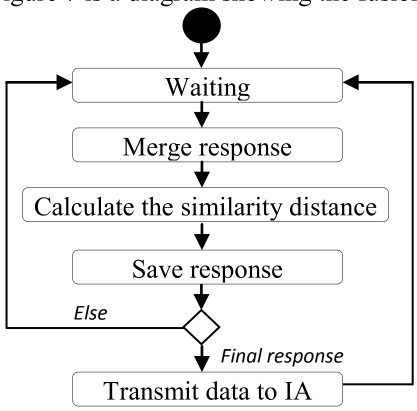

Figure 7. Activity diagram of the fusion agent

3.3. Applying the Voronoi Algorithm

As aforementioned, the Voronoi diagram consists of creating zones relative to pre-selected points. A zone is defined by the collection of points that are closest to one of the points chosen in advance. In our case, the points represent stations and stops and are pre-determined according to their congestion. The Voronoi algorithm, adapted to our study (the mutimodal information system) is presented below:

Algorithm 1: adaptation of the Voronoi decompsition

1. **For all** preselected stations **Do**
2. **For all** non-visited stations **Do**
3. calculate the distance with preselected stations for zoning
4. Select the minimum distance
5. Allocate the station to the adequate zone
6. **End For**
7. **End For**
8. Update zones
9. **End**

3.4. Algorithm relative to the search space

This algorithm is used by the directory agent to determine the search space when dealing with a route request. The search space consists of providing pairs (companies/zones) involved in a route request. The algorithm determines the zones and companies responsible for departure and arrival stations, then determines the search space according to one of four cases:

- The departure and arrival zones are identical and the arrival and departure stations belong to the same company: the search space is defined by this company's sub-network within this zone.
- The departure and arrival zones are different but the arrival and departure stations belong to the same company: the search space is defined by the union of this company's two sub-networks in these two zones.
- The departure and arrival zones are identical but the departure company and the arrival company are different: an adjacency graph is established between the companies to determine the intermediary companies which could take part to satisfy the request. The adjacency graph is represented by an adjacency matrix, and the exchange stations represent the intersection

between the different companies in the adjacency table. The Yen algorithm (Yen, 1971) to calculate the shortest routes is launched to determine the intermediary companies concerned. The request is broken down into numerous sub-requests according to the exchange stations.
- The departure zone and arrival zone are different, and the departure and arrival company are also different: firstly, the Dijkstra algorithm (Dijkstra, 1959) is applied to an adjacency graph between the zones to determine the relevant intermediary zones. Then the Yen algorithm (Yen, 1974) is applied to the adjacency graph in each of the relevant zones to determine the relevant intermediary companies as explained in the point above.

4. Results

In order to validate the proposed approach, we have used real data drawn from the timetables of several public transport companies in the city of Oran. We worked on a computer equipped with an i3-380 processor, 4 gigabytes of RAM and a 750 GB hard drive. The programming language used is Java (Dale, 2011) and the platform used for the multi-agent system is JADE (Bellifemine, 2007). The application can be accessed via a web portal. The data are taken from the timetables of three companies operating three different modes of transport, i.e. bus, tram, and train. The bus network consists of 182 nodes and 52416 daily arrivals/departures. The tram network consists of 32 nodes and 5760 daily arrivals/departures. The railway network consists of 12 stations and 1850 daily arrivals/departures.

We calculated the number of nodes involved in graphs when processing route requests in five types of architecture:

- Centralised architecture
- Architecture centralised by zone
- Our architecture, initialising the Voronoi algorithm with heavily congested stations...(1)
- Our architecture, initialising the Voronoi algorithm with medium congestion stations...(2)
- Our architecture, initialising the Voronoi algorithm with uncongested stations...(3)

Table 1 shows the number of nodes involved in a journey of 800 metres, table 2 for a journey of 5100 metres, and table 3 for a journey of 12000 metres:

Table 1. Number of nodes involved in processing a route request of 800 metres

Architecture	Number of nodes	Number of edges
Centralised	226	503
Centralised by zone	101	197
Voronoi (1)	36	63
Voronoi (2)	64	152
Voronoi (3)	94	193

Table 2. Number of nodes involved in processing a route request of 5100 metres

Architecture	Number of nodes	Number of edges
Centralised	226	503
Centralised by zone	173	274
Voronoi (1)	78	158
Voronoi (2)	123	215
Voronoi (3)	171	404

Table 3. Number of nodes involved in processing a route request of 12000 metres

Architecture	Number of nodes	Number of edges
Centralised	226	503
Centralised by zone	226	503
Voronoi (1)	112	232
Voronoi (2)	164	308
Voronoi (3)	226	468

From tables 1, 2, and 3 it is clear that the number of nodes involved when breaking down the network according to the Voronoi diagram is less than in other architectures. Processing requests within an architecture based on Voronoi operates over a sub-network and not the network in its entirety.

The choice of initialisation points (N) in our approach is very important. We have calculated the processing time whilst varying the number of points and their nature (heavily congested, medium congestion, or uncongested). We have tested three different route requests (800, 5100, and 12000 metres).

Figure 8 shows the calculation time in milliseconds (ms) in each case. The curves on the left give the response time when initialising the Voronoi algorithm with three points, the curves in the middle show the response time when initialising the Voronoi algorithm with four points, and finally the curves on the right show the response time when initialising the Voronoi algorithm with five points. The curves in blue show the response time when initialising with heavily congested stations; those in red when initialising with medium congestion stations; and those in green when initialising with uncongested stations. The results clearly show that initialising the algorithm with heavily congested stations offers the best response times, regardless of the number of points.

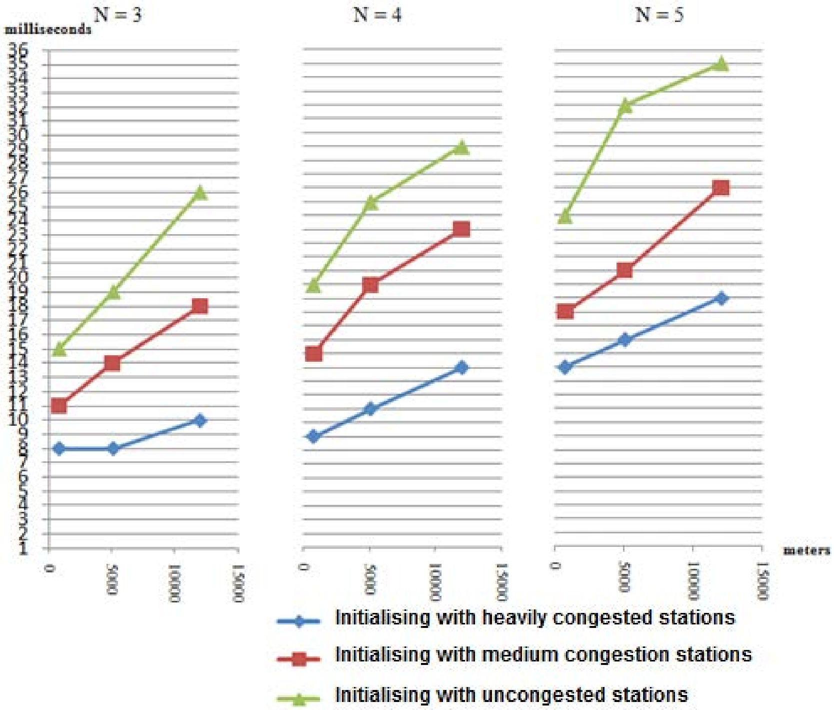

Figure 8. Comparison of the response times depending on the Voronoi initialisation

The following figure gives a preview of our programme being used online. The screenshot on the left shows access via a computer whilst the one on the right gives a preview of running the programme on a mobile phone.

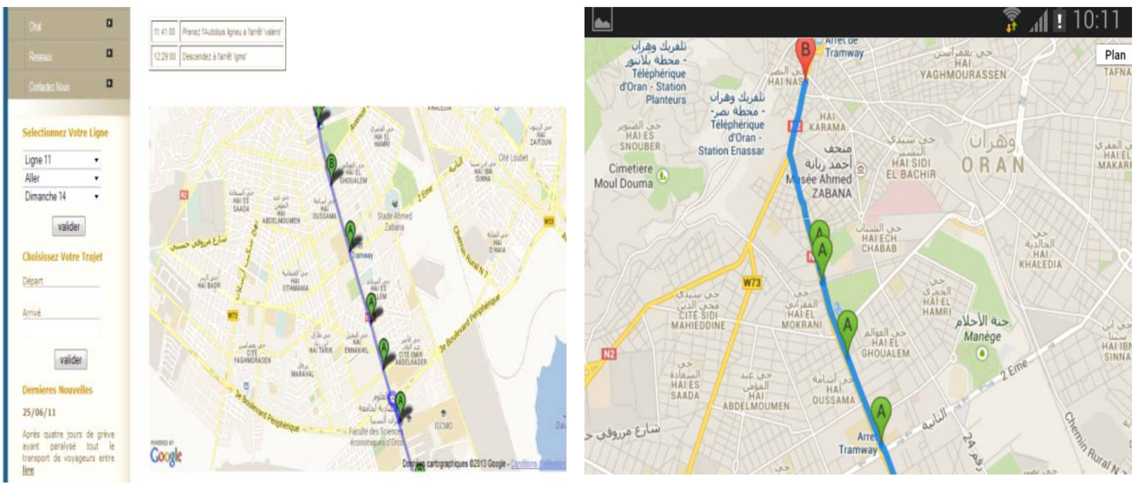

Figure 9. A preview of our system being used online

5. Discussion

The results in tables 1, 2, and 3 show that the number of nodes involved in processing itinerary requests within a centralised architecture is a constant 226 nodes. This number represents the total number of stops and stations of all transport companies belonging to the system. The centralised architecture takes into account all the networks of all the companies, regardless of the journey distance. The centralised architecture requires the transport companies to share their information. The sharing of information by a transport company poses the problem of controlling and modifying the data, besides issues concerning its market value. Transport companies stand to lose control of their data when it is shared and made available to a multimodal information system, plus this can cause update problems. The centralization of data is far better adapted to transport companies with small networks, where the number of nodes is limited, because it facilitates setting up and a better control of data. It is important to remember that in a transport network graph each station or stop is represented by several nodes: a physical node, and an event node for each departure or arrival (Pajor, 2009).

In partially centralised architectures (architecture centralised by zone), the number of nodes involved in processing requests varies according to journey distance (tables 1, 2, 3): 101 nodes for a journey of 800 metres, 173 nodes for a journey of 5100 metres, and 226 nodes for a journey of 12000 metres. The aim of an architecture centralised by zone is to group together the transport companies' networks which operate within the same geographic perimeters and to create a single network. In this case, when processing a route request, it is the networks of all the companies which belong to the zone that are taken into account: the longer the journey, the higher the probability of passing through several zones. In an architecture centralised by zone, the number of nodes involved depends on the journey distance and on the number of zones relevant to processing the request. The distribution of processes according to geographic zones can work around breakdowns more effectively than a centralised architecture, but who owns the information put at travellers' disposal is always an issue, especially in cases of inaccurate information.

The results obtained when processing requests within our proposed architecture show that the number of nodes involved is significantly lower than the numbers of nodes involved in a centralised architecture and an architecture centralised by zone. This considerable reduction in the number of nodes in comparison with other existing architectures can be explained by the fact that requests are processed using the transport companies' sub-networks. In effect, the aim of our work is to create the best zones in order to manage travellers' requests most efficiently. Nevertheless, the number of nodes involved in processing a request can change for the same route, depending on the initialisation of the Voronoi algorithm. Initialising the Voronoi diagram with heavily congested stations allowed the number of nodes involved to be advantageously minimised: 36 nodes for an 800-metre journey, 78 nodes for a 5100-metre journey, and 112 nodes for a 12000-metre journey. This number increases when initialising with medium congestion stations, and peaks when initialised with uncongested stations. Initialising with heavily congested stations clearly gives the best results, because they allow for zones with a heavy concentration of traffic. The choice of initialisation points remains difficult, and confronts the cold start problem, familiar to clustering algorithms. Numerous works have suggested solutions for initialising clustering algorithms (El Agha and Ashour, 2012; Reddy and Jana, 2012).

Figure 8 provides a visual presentation of the response times between different initialisations of the Voronoi algorithm diagram when processing a request according to journey distance and the number of zones chosen. Initialising with heavily congested stations provided the shortest time responses. The calculation time increases slightly with an increase in the number of zones, due to the number of messages exchanged between agents. It is necessary, therefore, to find the right equilibrium between the number of zones created and the number of messages exchanged between the agents. These should be paired with a good selection of initialisation points for the Voronoi algorithm, which could potentially be located using data analysis techniques. Finally, if choosing uncongested stations is the most costly in terms of response time, it would be interesting to experiment on a national level and test route requests in secluded villages or urban and suburban neighbourhoods.

Moreover, our architecture based on Voronoi diagrams offers transport companies the autonomy of not being forced to disclose their data. Transport companies retain control of information and our system becomes a mediator between the information systems of the various transport companies. The independence offered to companies should encourage them to integrate our system.

6. Conclusions

In this project we have proposed a multimodal traveller information system which handles requests concerning itineraries and information about exploring tourist attractions. This dual purpose system satisfies the needs of its clients by offering them a single portal for their journeys despite the existence of numerous companies. But it also satisfies transport companies needs' by eliminating the necessity for them to share data of commercial value. We have suggested breaking down all the companies' networks along the lines of the Voronoi diagram in order to minimise the number of nodes involved in processing itinerary requests. Upon receiving a route request, the system breaks it down into sub-requests and selects the relevant zones and companies. The mobile agents collect the replies to these sub-requests, which are brought together to form the final solution for the traveller. Choosing the initial points of the decomposition algorithm is often crucial: in retrospect, our system would benefit from analysis of data in order to automate the choice of points, as well as protocols on negotiation and cooperation between the agents for managing the network when services are disrupted. Additionally, the project could be advanced for application on a national level.

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USAGE OF PRODUCTION FUNCTIONS IN THE COMPARATIVE ANALYSIS OF TRANSPORT RELATED FUEL CONSUMPTION

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This contribution aims to examine the relationship between the transport sector and the macroeconomy, particularly in fossil energy use, capital and labour relations. The authors have investigated the transport related fossil fuel consumption 2003 - 2010 in a macroeconomic context in Hungary and Germany. The Cobb-Douglas type of production function could be justified empirically, while originating from the general CES (Constant Elasticity of Substitution) production function. Furthermore, as a policy implication, the results suggest that a solution for the for the reduction of anthropogenic CO2 driven by the combustion of fossil fuels presupposes technological innovation to reach emission reduction targets. Other measures, such as increasing the fossil fuel price by levying taxes, would consequently lead to an undesirable GDP decline.

Keywords: production function, environmental pollution, transport emission, fossil fuels

1. Introduction

The neoclassical theory of economic growth and the development of constant elasticity substitution production functions in the 20th century are closely connected. Solow's pioneering contribution (Solow, 1956) did not only create a new dynamic macroeconomic theory, but a new type of aggregate production functions was created. Arrow et al. (Arrow et. al., 1961), de Brown and Canin (de Brown et. al., 1963) continued to develop the theory of constant elasticity of substitution production functions. "*During the 1970s, many economists tried to generalize the CES function to allow variations of the elasticity of substitution. These attempts showed such generalization is possible under very limited circumstances. Aside from such generalizing attempts, the CES function* (Constant Elasticity of Substitution) *obtained large attention after the invention of the taste-for-variety model: Spence* (Spence, 1976) *for the continuum variety case and Avinash and Stiglitz* (Avinash, Stiglitz, 1977) *for the discrete variety case."*(Saito, 2011) The concept of production function in economics is interpreted as the transformation of production factors (e.g. labour, capital goods, fossil fuels, land, and air) to other goods (emissions). In essence the "production decision" is the choice of production factors and the amount of outputs. The idealized assumption of production theory is that of the company as a unit of economy making rational decisions. This presupposed that every company possesses all available information and strives to the maximum achievable profit (Kerepesi, Romvari, 1993). *"CGE models (*Computable General Equilibrium*)* are now extensively used in studies of the economy–energy–environment nexus at the national (Bergman, 1988; Conrad, Schröder, 1993; Beauséjour et. al, 1995; Lee, Roland-Holst, 1997; Goulder, 1998; Conrad, 1999) and regional levels (Despotakis, Fischer, 1988; Li, Rose, 1995). *The popularity of CGEs in this context reflects their multi-sectoral nature combined with their fully specified supply-side, facilitating the analysis of economic, energy and environmental policies."* (Allan et.al., 2007) Based on the introduced theoretical background, this article aims to analyse the profit-oriented economic actors especially focusing on their transport related fossil fuel consumption in Hungary and

Germany. Further on authors show Cobb-Douglas Production Function (derived from CES production function) as a basic of CGE model.

2. Methodology

Cobb-Douglas production functions are widely used in consumption and production theory. Cobb and Douglas studied the contribution of each resource to the economic performance of the economic segments of the national economy *(Cobb, Douglas, 1928; Maeda, 2010).* In the below described model below described it is assumed that the economy is closed, and the input parameters for the produced output are capital, labour and fossil energy. The energy sources are imported. The economy is considered closed except for the energy sources (that is, export and import processes are excluded) and externalities were not taken into account. The usage of fossil fuel generates carbon dioxide emissions (Szendro, Torok, 2014; Shiwale et. al., 2014). Without the technological development, the efficiency of energy conversion for internal combustion, engines are constant so fossil energy consumption and carbon dioxide emission rates are linked (Vass, Német, 2013;Domanovszky, 2014). In this model fossil fuel consumptions were considered as a parameter of production.

Figure 1 illustrates the conceptual approach of deriving, the simplified Cobb-Douglas production function from the CES production function. Further on the Cobb-Douglas production function is used. Following a formal deduction, such functions will be estimated using time series data from two European countries.

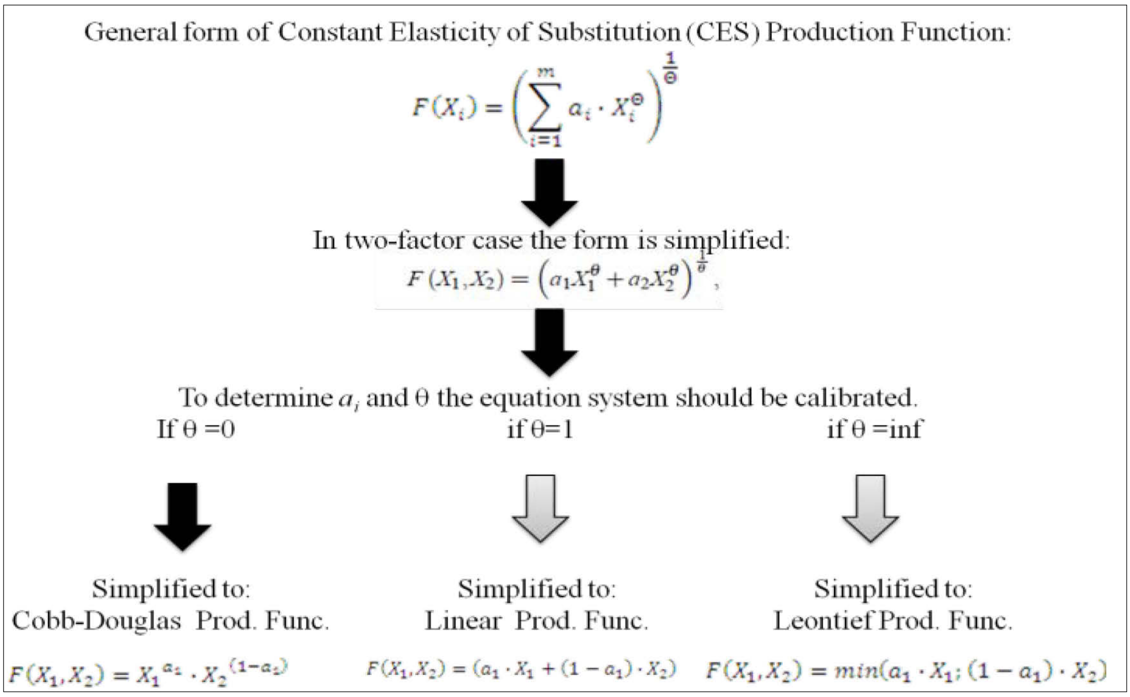

Figure 1. Visualisation of the model workflow
(source: own representation)

The variables of the analysis and respective data sources are presented below. The time horizon of the analysis is 2003 through 2010. Despite of the on-going technological changes, in the investigated period, no significant technological changes were found, therefore production function is considered constant:

- Y: GDP [Billion HUF[1]/year] – *source: Eurostat*
- Q: number of consumed consumer basket [piece[2]/year] – *The World Factbook (ISSN 1553-8133)*

[1] HUF: currency of Hungary
[2] The consumer basket is a set of products that the population consume in one year. These are products and services purchased from the market. Partly methodological, partly for technical reasons, certain purchases for (property) are not included. In our model, the population is assumed proportional to the number of product units.

- p: price of consumer basket [HUF/piece] - algebraically calculated
- F_c: Consumed fossil fuel [million litre/year] – *source: Trading Economics http://www.tradingeconomics.com/*
- P_f: Price of fossil fuel [HUF/litre/year] *source: The Automobile Association Limited http://www.theaa.com/*
- K: Number of companies [piece/year] – required to composite goods; *source: Eurostat*
- L: Number of employees [capita/year] – required to composite goods; *source: Eurostat*
- r: Estimated unit cost of capital investment, assuming a maximum investment readiness [HUF/company/year] – required to composite goods; *source: Economy Watch (http://www.economywatch.com/)*
- w: yearly gross wage [HUF/capita/year] – required to composite goods; *source: EuroMonitor (www.euromonitor.com)*
- β: price of composite goods [HUF/piece] – algebraically calculated
- R: composite goods [piece] – algebraically calculated
- Ψ: Cobb Douglas parameter – algebraically calculated
- ρ**:** technological parameter, $\rho = \frac{1}{(1-\sigma)}$, where σ is the parameter of constant elasticity

Let *F* be the production function (assuming a constant elasticity of substitution - CES), in general:

$$Q = F(K, L, F_c) \tag{1}$$

In other words, the output (Q) will change according to the used amount of capital (K), labour (L), and fossil fuels (F_c). The decision problem of economic actors is described by a nested binary model in order to be able to use simplified tools of mathematics. Capital (K) and labour (L) are combined in a composite product (R). Then the CES production function can be rewritten as (2):

$$F(K, L, F_c) = G(R, F_c) \tag{2}$$

Let *G* and *H* be production functions with constant elasticity of substitution (3) (4):

$$G(R, F_c) = (\Psi \cdot R^{\rho} + (1 - \Psi) F_c{}^{\rho})^{1/\rho} \tag{3}$$

where

ρ is the elasticity rate of fossil fuels (F_c) and composite product (R)

$$R = H(K, L) = (b_1 K^{\theta} + b_2 L^{\theta})^{\frac{1}{\theta}} \tag{4}$$

where

θ is the elasticity rate of capital (K), labour (L)

b_1, b_2 are the parameters

Then CES production function as an embedded binary production function will be as below (5):

$$F(K, L, F) = (\psi \left\{ (b_1 K^{\theta} + b_2 L^{\theta})^{\frac{1}{\theta}} \right\}^{\rho} + (1 - \psi) F_c{}^{\rho})^{\frac{1}{\rho}} \tag{5}$$

3. Calibration of production function

Taking into account equations (1) - (5) and the related assumptions of constant elasticity of substitution production function, the model calibration can be done according to the below presented two equations. So the coefficient and exponent parameters of the production functions with constant elasticity of substitution can be determined based on (6), (7):

$$\psi \cdot \left(\frac{F_c}{Q}\right)^{\rho} = \frac{P_f \cdot F_c}{Y} \tag{6}$$

$$(1 - \psi) \cdot \left(\frac{R}{Q}\right)^{\rho} = \frac{R \cdot p}{Y} \tag{7}$$

Equation (6) and (7) describes the connection between the prices and the volumes of output, and the used resources (composite goods and fossil energy). The correctness of the applied equations can be accepted if general form of CES function can be derived from them:

$$\psi \cdot \left(\frac{F_c}{Q}\right)^{\rho} = \frac{P_f \cdot F_c}{Y} \tag{8}$$

$$\psi \cdot \left(\frac{F_c}{Q}\right)^{\rho} = \frac{F_c \cdot P_f}{Q * p} \tag{9}$$

$$\psi \cdot \left(\frac{F_c}{Q}\right)^{\rho-1} = \frac{P_f}{p} \tag{10}$$

$$\psi = \left(\frac{F_c}{Q}\right)^{1-\rho} \frac{P_f}{p} \tag{11}$$

$$\left(\frac{F_c}{Q}\right)^{1-\rho} = p \frac{\psi}{P_f} \tag{12}$$

$$\frac{F_c}{Q} = p^{\frac{1}{1-\rho}} \cdot \left(\frac{\psi}{P_f}\right)^{\frac{1}{1-\rho}} \tag{13}$$

Finally, equation (13) is the general form of CES production function (Temple, 2012):

$$\frac{X_i}{Y} = p^{\frac{1}{1-\rho}} \cdot \left(\frac{\beta_i}{w_i}\right)^{\frac{1}{1-\rho}} \tag{14}$$

Hence the calibration equations can be accepted.

4. Results

The calibration process was carried out for every year and got the following results (Table 1) for Hungary and Germany as well:

Table 1. Results of calibration

Country	Hungary		Germany	
Year	**Cobb Douglas parameter (ψ)**	**Techno-logical parameter (ρ)**	**Cobb Douglas parameter (ψ)**	**Technological parameter (ρ)**
	{-}	{-}	{-}	{-}
2003	.0350	-.0014	.0130	.0008
2004	.0322	.0006	.0140	-.0007
2005	.0332	.0026	.0142	.0005
2006	.0373	.0000	.0169	-.0003
2007	.0342	-.0018	.0153	-.0004
2008	.0338	-.0020	.0117	-.0011
2009	.0321	-.0015	.0150	-.0003
2010	.0329	-.0003	.0173	-.0002

(source: own results)

As it can be seen - according to the estimation that has been done - the constant elasticity substitution production function F(ρ) parameter value is varying close to zero, in case of both Germany and Hungary. The same results were found in Japan for fossil fuel consumption modelling (Maeda, 2010) and for SO_2 emission in China (Xu, Masui, 2008). The Cobb-Douglas production function in this case is by definition:

$$F(K, L, F) = \left\{(b_1 K^{\theta} + b_2 L^{\theta})^{\frac{1}{\theta}}\right\}^{\psi} \cdot F_c^{(1-\psi)} \tag{15}$$

where $\psi \in \{0,1\}$ is known to be the share of consumption of R (as composite goods, so that 1-ψ is of F_c). From (15) - if F is a production function - then the marginal production of R and F_c is (16) and (17):

$$\frac{\partial F}{\partial R} = \psi \cdot \left(\frac{F_c}{R}\right)^{1-\psi} \tag{16}$$

$$\frac{\partial F}{\partial F_c} = 1 - \psi \cdot \left(\frac{F_c}{R}\right)^{-\psi} \tag{17}$$

after that ratio of marginal production (RMP) is algebraically calculated (18):

$$\mathrm{RMP} = \frac{\partial \mathrm{F}/\partial \mathrm{R}}{\partial \mathrm{F}/\partial \mathrm{F_c}} = \frac{\psi}{1-\psi} \cdot \frac{\mathrm{F_c}}{\mathrm{R}} \tag{18}$$

Since the relative change of a function is given by the derivative of its logarithm value (18) one obtains:

$$\sigma = \frac{\mathrm{d \cdot ln(RMP)}}{\mathrm{d(F_c/R)}} = \frac{1}{\mathrm{F_c/R}} \tag{19}$$

Therefore the consumption share is fixed and so σ = 1. This yields to the previously known conclusion that the CES function must converge to the Cobb-Douglas as $\rho \to 0$ (Saunders, 2008*)*. As expected, the ρparameteralues are varying close to zero. This suggested to use the Cobb-Douglas type in the following (Wei, 2006), (van der Werf, 2007) in combination with the two estimated parameters.

5. Analysis and discussion

The resulting function is:

$$\mathrm{Q} = \mathrm{R}^{\psi} \cdot \mathrm{F_c}^{(1-\psi)} \tag{20}$$

$$\mathrm{Y} = \mathrm{F_C} \cdot \left(\mathrm{R}^{\psi} \cdot \mathrm{F_c}^{-\psi} - \mathrm{P_f}\right) \tag{21}$$

Figure 2 (a and b) visualises the data collected for the two cases investigated based on (21):

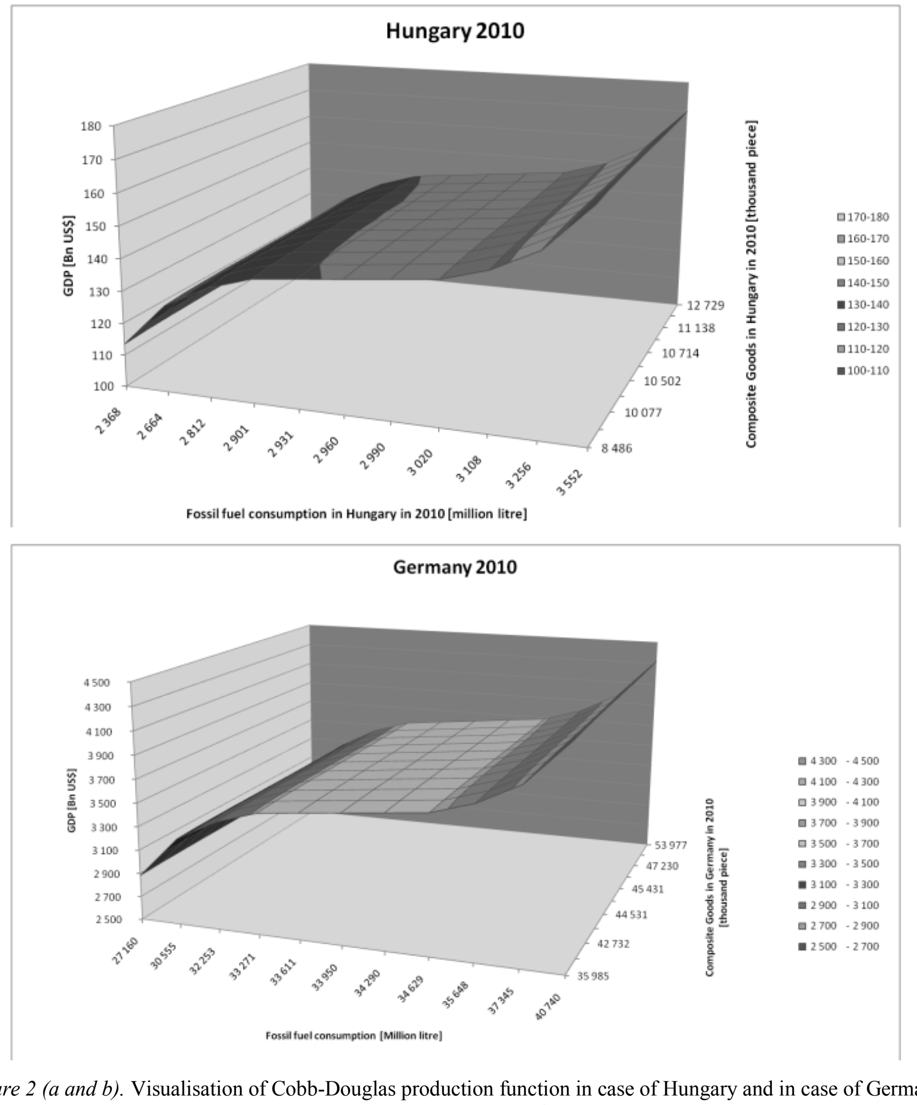

Figure 2 (a and b). Visualisation of Cobb-Douglas production function in case of Hungary and in case of Germany (source: own representation)

Figure 3 shows that the fossil fuel used for transport purposes has a strictly increasing marginal production cost curve. That means, if the production increasing then the unit cost is increasing, it is more costly to produce goods. **With other words, increasing the fuel price by imposing taxes in order to increase fuel price to reach emission targets will hurt the economy**.

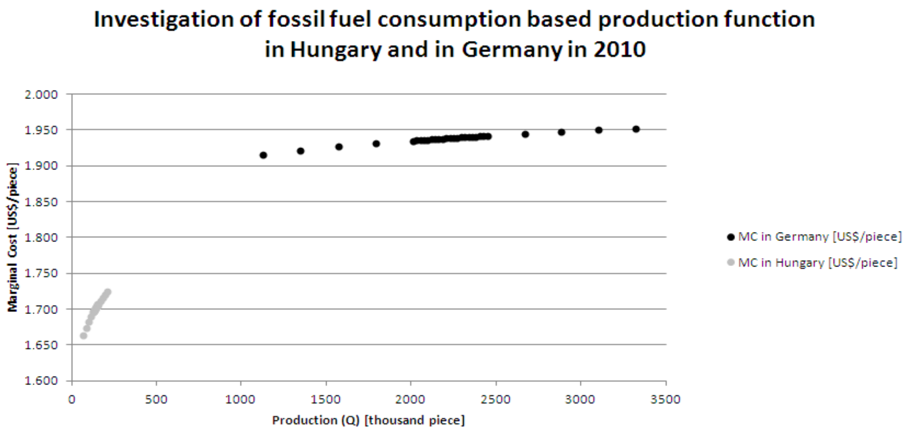

Figure 3. Investigation of fossil fuel consumption based on production function in 2010
(source: own representation)

In consequence it can be stated that the obvious solution to reach emission reduction target could be technological innovation to avoid the undesirable trends of GDP decline. It has to be taken into account that technological innovations and R&D activities have their own costs. **However, only the technological development can complete the emissions reduction without harming the economy**. Accordingly, the common objectives to reduce the environmental pollution (Torok, 2014, Mitsakis, 2014), in particular greenhouse gas emissions, will depend on the substitution of composite goods (that contains labour work and investment) and fossil fuels. Further statistical analysis indicates that the Cobb-Douglas coefficients have not changed significantly in this case.

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A GREEN CORRIDOR BALANCED SCORECARD

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Green transport corridors represent trans-shipment routes with a concentration of freight traffic between major hubs and long distances of transport marked by reduced environmental and climate impact. Important characteristics of green corridors are their network structures, their transnational character and their high involvement of public and private stakeholders, including political level requiring new governance models. Network-oriented controlling of green transport corridors require new concepts and instruments concentrating on multi-dimensional evaluation of collective strategies and processes in an international environment with a focus on cross-company aspects.

Until now the scientific discussion focusses on different sets of Key Performance Indicators (KPI) for monitoring and management of green corridors, which mainly cover sustainable aspects of green corridor development by neglecting a network-oriented controlling approach so that a general concept for green corridor controlling is still missing. The current KPI approaches emphasize the operational aspects of the corridor performance so that a strategic management control system is needed to safeguard an efficient, innovative, safe and environmental friendly long-term development.

The paper will present and discuss a management control system for green supply chains based on the balanced scorecard concept and link the ongoing scientific discussion to recent research results about green corridor management. The presented green corridor balanced scorecard tries to solve the strategic weakness of the existing green corridor controlling approaches by integrating cooperative and network-oriented concepts from supply chain management.

Keywords: Green Transport Corridors, Management Control Systems, Networks, Balanced Scorecard, Key Performance Indicators

1. Introduction

Since the EU White Paper on Transport in 2011 the concept of green transport corridors enjoys high attention in the EU transport policy development. Green transport corridors can be characterized as European trans-shipment routes with concentration of freight traffic between major hubs and relatively long distances of transport marked by reduced environmental and climate impact, while increasing safety and efficiency with application of sustainable logistics solutions, inter-modality, ICT infrastructure, common and open legal regulations and strategically placed trans-shipment nodes. In order investigate and implement the green corridor concept the EU Commission initiated several EU-funded regional development projects to realize different approaches and ideas of this concept.

The main characteristics of green transport corridors are related to green or sustainable aspects, multimodality and network concepts (Hunke and Prause, 2013; Prause and Hunke, 2014b), so green supply chain management represents one important source for the theoretical foundations. In the context of green supply chain management, there exists interdependency between conventional supply chain management and eco-programs (Sarkis, 2001). This includes the approach on how ecological aspects can be considered in the whole business processes in the most effective way.

When it comes to management control systems for supply chains a literature review reveals that specific controlling topics in this context have been discussed by several scholars but no integral theory or conceptual framework papers about supply chain controlling exist in the leading English speaking supply chain journals except the article of Seuring (2006), who introduced in the German supply chain controlling concepts explaining the dominance of references of German scholars in this field. Consequently, a comparable situation can be stated for green supply chains and green corridors, which have gained attention in recent years but beside the discussion of certain controlling tools still no single concept or theory exists in this field (Seuring and Müller, 2008; Göpfert, 2013).

Since green corridors are imbedded into an international network environment new concepts and instruments concentrating on multi-dimensional evaluation of collective strategies and processes are required, taking into account international and cross-company aspects, but such a network-oriented controlling is still in the beginning (Sydow and Möllering, 2009). A widespread approach for a network-oriented controlling is based on the balanced scorecard concept of Kaplan and Norton (1996), which has been transferred and adapted to a cross-company interactions leading to “cooperative scorecards” of “network-balanced scorecards” (Hippe, 1997; Lange et al., 2001; Hess, 2002).

The current scientific discussion related to performance monitoring of green corridors focusses on different sets of Key Performance Indicators (KPI) for management of green corridors, which are mainly covering sustainable aspects of green corridor development by neglecting a network-oriented controlling approach so that a general concept for green corridor controlling is still missing. Furthermore, the KPI approach emphasizes the operational aspects of the corridor performance so that a strategic management control system is needed to safeguard an efficient, innovative, safe and environmental friendly long-term development.

The paper will present and discuss a balanced scorecard approach for green corridors and link the results to the ongoing scientific discussion about green supply chain management. In order to solve the strategic weakness of the existing management control concepts for green corridor the new green corridor balanced scorecard approach will integrate cooperative and network-oriented concepts. The scientific discussions will be shown that this green corridor balance scorecard approach has potential to serve as a suitable controlling instrument for managing an effective and efficient green corridor development, which is independent of specific governance models.

2. Supply Chain Controlling

One way to characterize a transport corridor is to understand the corridor as a conglomeration of different stakeholders, which act along a defined geographical area in order to achieve different goals but with the same objective to reduce costs, increase efficiency, minimize environmental impact and create safe and sustainable logistics solutions (Hunke and Prause, 2013; 2014a). This approach based on the interaction of acting organisations along their supply chains in the corridor stresses a network perspective from organisation's point of view on the collaborative practices and integrative behaviours of the stakeholders in the supply chains (Lee, 2005). As the stakeholders act in a coherent sense and are located in a certain geographical area a green transport corridor can be described as a tubular service cluster.

An interesting example for a green transport corridor is the East-West Transport Corridor (EWTC), linking Southern Sweden, Lithuania, Belarus and Ukraine, where the tubular cluster has the following shape (Prause and Hunke, 2014b):

Figure 1. Green transport corridor as a tubular service cluster
Source: Prause and Hunke, 2014a

Figure 1 highlights already that the network-oriented consideration of a green transport corridor concerns questions like intercultural issues related to different business cultures and models as well as different legal systems, which are beyond ordinary network topics like collective processes and strategies of the heterogeneous set of network stakeholders. Therefore, for the monitoring and controlling of those networks there are instruments required, which are able to evaluate these collective strategies and processes related to the demand of a holistic coverage, planning and development for such networks.

Ackermann (2003) proposed for the controlling of a supply chain a "supply chain balanced scorecard", where the traditional perspectives related to finance, processes, clients and learning are still maintained but they are oriented on the integral supply chain instead on unique companies or stakeholders. Weber (2002) took one step further and created cross-company balanced scorecard for a supply chain, which keeps the two traditional perspectives finance and processes but he replaced the other two traditional perspectives by two new ones, which he called cooperation intensity and cooperation quality:

- Financial perspective,
- Process perspective,
- Cooperation intensity, and
- Cooperation quality.

In his proposal Weber subsumed under the cooperation intensity perspective the "hard factors" of cooperation like data exchange, whereas he used the cooperation quality to focus on the "soft factors" like trust. Weber's proposal for a supply chain balanced scorecard has the following structure:

Perspective	Strategic target	Indicator	Measures
Financial Perspective	Increase return of SC	Increase RoA of SC by x %	Outsource warehousing Reduce working capital
	Try to achieve cost ledership	Reduce logistics costs in SC per unit by x %	Bundling of partner capacities
Process Perspective	Max. lead time client: 10 days	Reduce SC lead time to 10 days	Cross partner process optimization
	Increase flexibility of operations	Increase freezing point in % of lead time of SC	Flexible parts, postponement
Perspective of Cooperation Intensity	Increase data exchange between SC partners	Number and frequency of exchanged data sets	Improve IT - networking of SC partners
	Increase coordination between SC partners	Number of necessary coordination meetings	Systematic management of notes and minutes
Perspective of Cooperation Quality	Increase trust and satisfaction level between SC partners	Establish indicators for trust and satisfaction	Define common visions and guidelines
	Increase cooperation quality	Number of uncooperative solved conflicts	Establish „referee" for the SC

Figure 2. Weber's modified Supply Chain Balanced Scorecard
Source: Sydow and Möllering, 2013

Together with his proposal Weber (2002) pointed out that a large number of proposed scorecards for the evaluation of supply chains are only slightly modified classical balanced scorecards without any significant network perspective. The challenge to find an appropriate approach for an effective network controlling lies in the fact that networks are rather dynamic structures, whereas most of the existing controlling concepts are rather targeting on stable structures, so that more flexible management control systems are needed (Sydow and Möllering, 2013).

3. Monitoring of Green Corridor Performance

Most of the green corridor initiatives represent EU-funded regional development projects due to the political background of the green corridor concept with its links to the EU White Paper on Transport 2011. Consequently, the implementations of green transport corridors are based of different understandings and realizations of the concept making it necessary to evaluate, compare and benchmark existing green corridor implementations.

Already for the monitoring of green transport corridors there are many different attempts starting from individual companies and industry representatives up to international government level. An important case was the EU-funded project "EWTC2" within the BSR Interreg IVB Programme, where for the first time a "Green Corridor Manual" based on the East-West-Transport-Corridor was developed trying to give a holistic and consistent monitoring concept for multi-modal sustainable transport (Hunke and Prause, 2013). An important element of the Green Corridor Manual was a proposal for a set of Key Performance Indicators (KPI), which measures different aspects of the performance of transport chains.

The set of KPI can be separated into two subsets of indicators measuring enabling and operational criteria. The enabling indicators describe the settings and characteristics of the transport chain in regard to the hard infrastructure. The operational indicators characterise the soft infrastructure including the information and communication systems, which support the transport logistics services, the aspects related to regional, national and international policies and the set of regulations, which apply to all stakeholders. In this sense, operational aspects describe the geographical settings as such, the transport and logistics solution by involving new and innovative business models. The implementation of transport techniques will have also a direct impact on the performance of a transport chain measured by given KPIs.

Performance areas	Operational indicators	Enabling indicators
Economic efficiency	Total cargo volumes On time delivery	Corridor capacity
Environmental efficiency	Total energy use Greenhouse gases, Co2e Engine standards ISO 9001 dangerous goods	Alternative fuels filling stations
Social efficiency	ISO 31 000 ISO 39 000	Safe truck parking Common safety rating Fenced terminals

Figure 3. Performance Indicators
Source: EWTC2 Green Corridor Manual, 2012

Figure 3 gives an overview about the KPIs, which were selected from the EWTC2 project and which have been tested during the project life-time. As can be seen from the table the performance areas of the EWTC2 KPI system are covering economic, environmental and social dimensions.

Additionally to the table of performance indicators, often in a more detailed way the enabling factors are described by a corridor dashboard aiming at connecting the short-term KPIs and enabling KPIs by visualizing capacity, accessibility and performance. Thus, the dashboard stimulates improvements of the corridor infrastructure and facilitates the cooperation of all stakeholders along the corridor in order to improve total performance (EWTC2 Green Corridor Manual, 2012).

There are different aspects influencing the performance of a green transport corridor. In the EWTC approach proposes a KPI based on economic, environmental and social aspects representing the three dimensions of efficiency (EWTC 2012). But the KPI system of EWTC emphasises hard factors whereas the soft factors are neglected. Prause (2014b) illustrated that the performance of green transport corridors depends heavily on the long-term success of their underlying hubs, representing logistics clusters, and the sustainable development of these logistics clusters is strongly impacted by the "soft factors", which are usually linked to the cluster governance.

The importance of soft factors in the context of green transport corridors also appear due to its multi-modal nature. Sanders and Premus (2002) stressed the function of information in supply chain management as glue that hold the collaborating business structures in the supply chain together and Evangelista (2002) stated that the role of ICT in supply chain management can be described as key integration element. Daduna et al. (2012) pointed out that intermodal transport is built of networks of logistics companies and components so their management depends on powerful ICT-systems. All these results show the relevance of "soft factors" like trust, inter-cultural skills, innovation and cooperation skills for the long-term success of green corridors.

An important and successful case for a green transport corridor concept is the EWTC business model that is based on multi-modal logistics solution and that offers a value proposition towards the client (Kusch et al., 2011). The EWTC corridor offers full logistics service for the shipment of 20, 40, 45 feet containers, trailers, semi-trailers and trucks with a fixed schedule and pricing between Klaipeda in Lithuania and Ilyichevsk near Odessa in Ukraine. The full logistics services are offered via an one – stop – shop (EWTC-OSS; http://www.vikingtrain.com) to the integrating the logistics services around the shuttle train "Viking" which realises the container transport between Klaipeda and Ilyichevsk with a 46% cost savings for compared to a truck transportation within a fixed time of 52h including border crossing and customs procedures. This offer is not only cheaper and faster than normal truck transportation; it also is greener due to the use of train transport.

4. Framework conditions of Green Transport Corridors

In order to characterise the framework conditions for green transport corridors it is important to get familiar with the main results of some of the most important logistics development project in the Baltic Sea Region. The starting point of all later green corridor initiatives was the BSR Interreg IIIB project "LogOn Baltic – Developing Regions through Spatial Planning and Logistics & ICT Competence", which was implemented 2006-2007 and aimed at depiction of the logistics status in the BSR after the EU enlargement in 2004. The empirical activities of LogOn Baltic showed that the landscape of inter-company logistics was dominated by larger production companies and logistics service providers together with their closed and company oriented ICT-systems in order to safeguard the control of their individual supply chains and to realise dedicated platforms for sourcing of transport services mainly from regional SME (Kersten et al., 2007; Kron and Prause, 2008).

The second important initiative with a strong impact on the green corridor activities in the BSR was led by the Swedish Logistics Forum and resulted into the formulation of six requirements on green corridors (Green Corridor, 2010):

- Sustainable logistics solutions with documented reductions of environmental and climate impact, high safety, high quality and strong efficiency;
- Integrated logistics concepts with optimal utilization of all transport modes, so called co-modality;
- Harmonized regulations with openness for all actors;
- A concentration of national and international freight traffic on relatively long transport routes;
- Efficient and strategically placed trans-shipment points, as well as an adapted, supportive infrastructure; and

- A platform for development and demonstration of innovative logistics solutions, including information systems, collaborative models and technology.

The six framework conditions comprise a couple of important characteristics for the organisation and structuring of green transport corridors. Since the stakeholders within a green corridor are composed of different institutions including public and private organisations of different size and intention, of special importance for the SME sector is the demand of "openness and harmonization for all actors" as well as "collaborative models and technology" stressing a more balanced and cooperative work of all kind of stakeholders in the green corridor.

The set of framework conditions of the Swedish Logistics Forum have to be completed by a set of quantitative indicators to allow the monitoring and controlling of the performance and development of the Green Transport Corridor. Here the two EU projects "SuperGreen" and "EWTC2" developed and delivered for the first time proposals for KPI (Hunke and Prause, 2013). Especially the "Green Corridor Manual" of the EWTC2 project fixed a set of recommendations and guidelines on how to implement the green corridor concept according to the EU freight agenda and as promoted by the EU Baltic Sea Strategy and trying to give a holistic and consistent monitoring concept for multi-modal sustainable transport (EWTC2 Green Corridor Manual, 2012). The EWTC approach was based on the results of the green corridor initiative of the Swedish Logistics Forum and the FP7 – project "SuperGreen".

A more detailed picture about the framework conditions of green corridors can be drawn by analysing the requirements for logistics ICT systems and in particular about integrated green corridor ICT systems. Already the results of the comparison of regions within the LogOn Baltic project brought to light that the BSR regions with higher logistics competence enjoyed a higher degree of ICT usage in logistics together with a significant higher level of outsourced logistics ICT services, but the outsourcing of logistics ICT solutions was laid on closed and company oriented systems (Kron and Prause, 2008). Expert interviews revealed that the landscape of inter-company logistics ICT systems was dominated by larger production companies and logistics service providers to safeguard the control of their individual supply chains and to realise dedicated platforms for sourcing of transport services mainly from regional SMEs (Prause et al., 2010).

In a comparable analysis Prause and Hunke (2014) summed up the main results and properties of the ICT systems of green corridor initiatives from BSR in order to formulate system requirements for an integrated green corridor ICT system. The analysis was able to fix a set of functionalities, technical requirements and organizational frame conditions for such integrated green corridor ICT systems:

- Open architecture,
- Oriented on standards,
- Focus on inter-operability and co-modality,
- Independence of technology,
- Endorsed and adopted by major freight ICT-systems providers and logistics operators,
- Support the European transport and logistics system to be more efficient and environmental-friendly, and
- Creation of a fair and balanced transport spot market within the corridors enabling market leaders and SMEs to interact at a low cost.

Especially the realization of the last condition represents a task far beyond a technical question, since the implementation is related to the political question of convincing the current big logistics players to open their closed ICT systems and to integrate these systems into the common logistics platform of the green transport corridor, which is directly related to a loss of their influence and market power.

Another rather political challenge for the whole green corridor is related to the creation of an open data base within the green corridor ICT system comprising freight tariffs and contracting conditions in order to be able to build green corridor spot market for logistics services. This requirement is related to the implementation of openness, transparency and trust among the stakeholders, which is rather an organizational or political task belonging to the sphere of the "soft factors" of the green corridor.

5. Indicators for Soft Factors

Weber's proposal was oriented on the needs of supply chains but like Prause (2014) proposed, due to the conventional proximity between supply chains and green corridor, to use Weber's ideas for constructing a green corridor balanced scorecard which includes the KPI system of the EWTC "Green Corridor Manual" and which respect also the frame conditions of green transport corridor. Prause and Hunke (2014b) exhibited that beside the criteria covered by be EWTC key performance indicators also other aspects like openness, transparency, fair and harmonised access regulations as well as cooperation aspects are common and characteristic frame conditions for green transport corridors which have to be integrated into a strategic management control system.

Consequently as acceptable Green Corridor Balanced Scorecard should again allow four perspectives including all important perspectives for green transport corridors and should additionally focus on the underlying network and cluster properties of a corridor. One possible approach for such a concept for a green corridor balanced scorecard which is in line with a controlling concept for supply chains has been elaborated and proposed by Prause (2014a). In this model four perspectives appear and two of them are dedicated to cooperation like in Weber's model.

Of special interest is the perspective concerning cooperation quality because here the "soft factor" aspects are covered. In accordance with the already discussed topics the model comprises four indicators for cooperation quality (Prause, 2014a):

- Openness
- Trust level
- Transparency level
- Conflict level.

Since all mentioned indicators have to be measured the usability of a green corridor balanced scorecard concept heavily depends on practical measures. Weber (2002) proposed for the measurement of trust level and conflict level and other measures are discussed in academic literature so that measures for trust and conflict levels can draw on established theories (DeLangen, 2004; Prause, 2010).

In contract the measurement of openness and transparency are rather topics of ongoing scientific discussions (Schnackenberg, 2009; Schnackenberg and Tomlinson, 2014). In the context of this paper openness is more oriented on open access to potential or real stakeholders of the corridor and its institutions and resources, i.e. is rather related to the issue of "harmonized regulations with openness for all actors", whereas transparency is more focussing on the accessibility of information. Nevertheless, the situation is still like Sheila Coronel (2012) pointed out, that there exists still a ratings paradox for openness and transparency with many measures but no "Super Index".

Despite the fact that there is no "super index" there are general measures for openness and transparency which are agreed among experts concerning governmental systems and which include the disclosure of spending and procurement data, open information portals for stakeholders and open meetings of institutions (Coronel, 2012).

In the context of the frame conditions of a green corridor there can be added the disclosure of service and pricing information of stakeholders in the corridor, information about received orders and turnovers according to stakeholders and company size in order to get aware about participation of SME in corridor services as well as information about the utilisation rate of common corridor resources compared to all resources. This is of special interest for the common corridor IT system because here a measure expressing the percentage of all corridor orders which are handled by the corridor IT system compared to those orders still handled by company owned IT systems can be interpreted as an acceptance rate of the corridor resources together with their regulations.

6. Balanced Scorecards for Green Transport Corridors

Coming back to Weber's (2002) integrated supply chain balanced scorecard approach, which was discussed in chapter 2, the cross-company aspects of a supply chain were covered by the two perspectives cooperation intensity and cooperation quality, describing the "hard factors" and the "soft factors" related to the cooperation in the supply chain. Since these two cooperation perspectives apply to green transport corridors in the same way like for supply chains it is recommendable to keep these two network perspectives in a controlling concept for green corridors.

More complicated is to decide whether the financial and process perspectives are appropriate from the controlling point of view for green corridors. The KPI system of the EWTC "Green Corridor Manual" used the "sustainability" perspective covering economic, ecologic and social aspects, thus from the EWTC understanding the financial and process perspective is integrated into the sustainability perspective. Consequently, it makes sense to take the "sustainability perspective" with the full EWCT-KPI system as a third perspective for a tentative green corridor scorecard.

In the classical balanced scorecard approach of Kaplan and Norton (1996) a fourth perspective is introduced. By comparing classical balanced scorecard approach with the proposal of Weber (2002) it turns out that learning, client and growth perspectives are missing. Since a green corridor enjoys a network or a tubular cluster structure, development and growth represent an important element for such a construction due to inter-organizational knowledge transfer among the network partners, the generation of innovations and new service design solutions for the clients as well as the implementation of process and organizational innovations in the corridor. Therefore, it is recommendable to integrate a growth perspective as the fourth dimension for the green corridor.

By summing up the done reflections and results concerning a Green Corridor Balanced Scorecard the four perspectives together with a set of possible indicators lead to the following situation:

- Sustainability perspective
  - Economic efficiency
  - Environmental efficiency
  - Social efficiency
- Growth perspective
  - Innovation activities
  - New services
  - Green corridor stakeholder fluctuation
  - TO of new services
- Cooperation intensity
  - Data exchange
  - Coordination needs
- Cooperation quality
  - Openness
  - Trust level
  - Transparency level
  - Conflict level

This balanced scorecard includes all important perspectives for green transport corridors and focusses on the underlying network properties of a corridor. Furthermore, it constitutes the KPI system of the EWTC2 project. The set of indicators is not complete and also the type of measurement and evaluation of the indicators is still open, but nevertheless the presented concept for a green corridor balanced scorecard is a further development and in line with a controlling concept for supply chains. In this sense the presented balanced scorecard represents an important stepping stone for a controlling concept for green corridors, but it is obvious that further research has to be done to mature a complete controlling concept for green transport corridors.

7. Conclusions

The concept of Green Transport Corridor plays an important role in the European transport policy but a powerful management control system for those corridors in still missing. Even for supply chains a literature review reveals that no integral theory or conceptual framework papers about supply chain controlling exist in the leading English speaking journals. The situation is slightly different among German speaking scholars, since a German supply chain controlling concepts exists in German literature.

By understanding green corridors as a regional network, which enjoys supply chain characteristics, methods of network-oriented controlling and supply chain controlling can be applied. In network-oriented controlling the balanced scorecard concept of Kaplan and Norton (1996) has been successfully adapted and further developed. An important step towards supply chain and network-oriented controlling was established by Weber (2002), who created a cross-company balanced scorecard for a supply chain, which consisted of four perspectives including the financial perspective, the process perspective, the two perspectives of cooperation intensity and cooperation quality. The two cooperation perspectives describe the “hard factors” and “soft factors” of the cooperation.

Based on these results the paper tries to integrate the results and experiences of important green corridor initiatives in the Baltic Sea Region in order to create green corridor balanced scorecard. First, the KPI system of the EWTC project is integrated into the scorecard in order to safeguard the “sustainability” perspective. Second, the growth perspective is integrated into the green corridor balanced scorecard in order to represent development and growth as important elements of such a corridor, since inter-organizational knowledge transfer, the generation of innovations and new service design solutions for the clients as well as the implementation of process and organizational innovations in the corridor are of vital importance. Finally, a fully developed balanced scorecard for green transport corridors needs not only the definition of appropriate perspectives, but it also requires a set of powerful indicators together with types of measurement and evaluation of the indicators. All these topics are still subject to research so that the presented balanced scorecard constitutes a first step towards a controlling concept for green corridors.

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DIPOLE APPROXIMATION IN THE CALCULATION OF THE PERTURBED VELOCITIES

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In this article we consider one of the approaches aimed at reducing time of calculation of aerodynamic characteristics of the studied objects using discrete vortex method. Also, accuracy assessment of calculation of aerodynamic characteristics was performed.

Analysis of the obtained dependences allows us to make a conclusion that the considered approach to the calculation of the functions of the mutual influence on the stages of formation of the system of linear algebraic equations, position of vortex sheet nodes as well as aerodynamic loads reduces hardware costs about three times, with a relative error of less than 4%.

Keywords: discrete vortex method, dipole approximation

1. Introduction

The efficiency of numerical methods for solving numerical aerodynamics problems depends on the entry requirements to the software and computer resources.

The modern level of computing technology allows solving effectively a wide range of numerical aerodynamics problems. However, in case of solving problems in nonlinear stationary and non-stationary setting there are significant problems related, first of all, with large duration of the calculation of the aerodynamic characteristics of a studied body that significantly complicates the solution of retrieval problems and reduces the efficiency of performance. Development and implementation of measures that aimed to reduce the requirements for software with available computing resources is an important task, it requires an analysis of all phases of the numerical modeling and computational algorithms.

Figure 1 shows the possible ways to improve the effectiveness of computational experiment:

– computing technology performance improvement (extensive way);
– analysis of the problems with the rational combination of numerical methods of research and engineering methods;
– rational mapping of the studied object, taking into account the particular features of the numerical method (quadrature with higher convergence rate, accounting of the results of the research on the methodology of calculation, etc.);
– optimization of algorithms of calculation (minimization of computational procedures, rational construction of software modules, etc.).

The most important of these approaches are:

– rationalization of calculation of mutual influence functions at the stage of the formation of system of linear algebraic equations (SLAE) matrix;
– calculation of the spatial position of the vortex sheet that descended from the surface of the studied body;
– calculation of the aerodynamic loads.

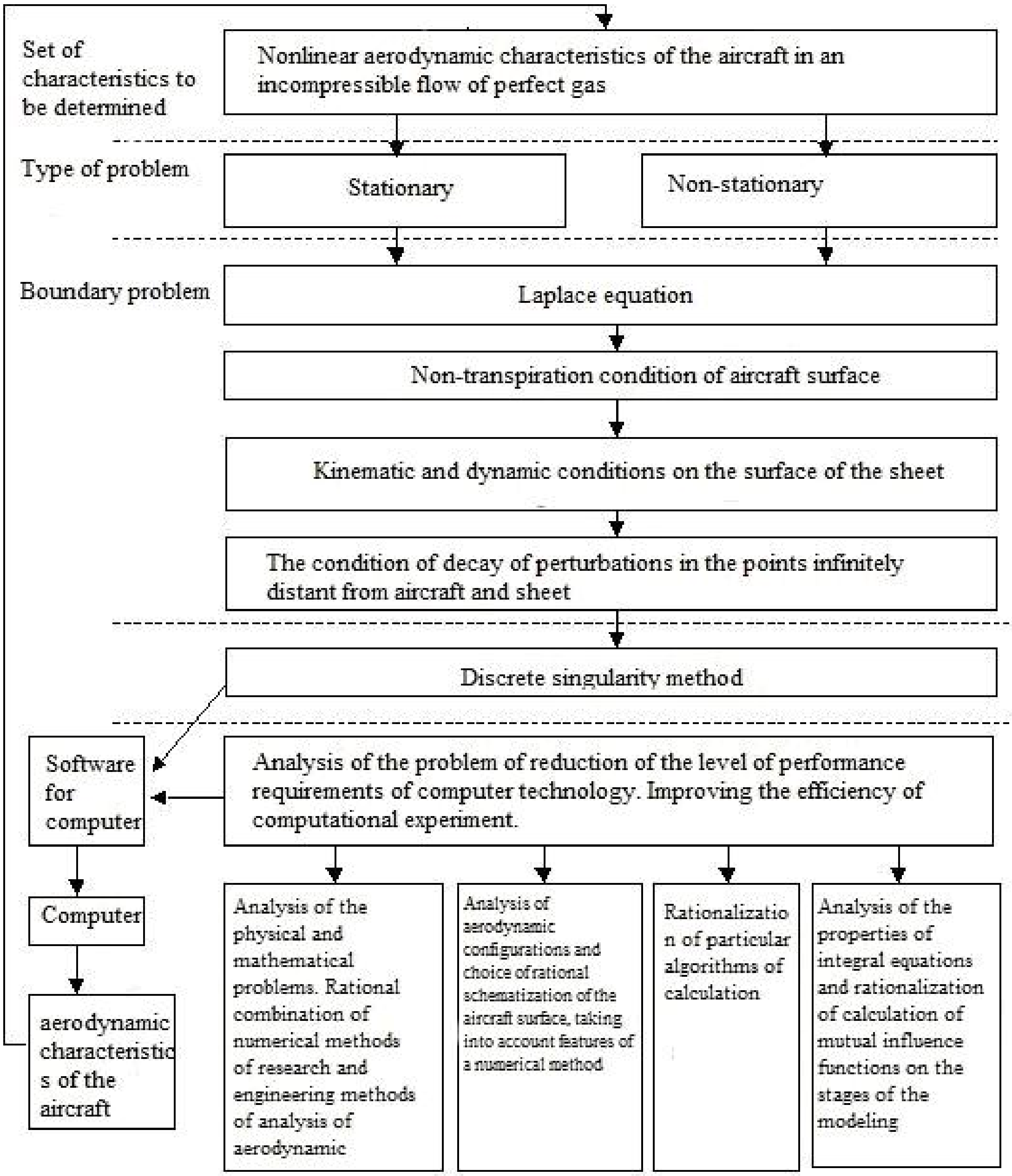

Figure 1. Ways of improving the efficiency of numerical experiment

2. Problem solving

From the assumption that the vortex frame through which describes the configuration of the body and the vortex sheet that descended from it, at a distance *R*, significantly exceeding its perimeter *P*, creates a dipole field with an intensity $\vec{d} = \vec{n}\Gamma S$, that is estimated by the module of the potential difference of flat panel the dipole potential:

$$\delta \le d\left(\frac{P}{R}\right)^2 . \quad (1)$$

This assessment allows you to make an assumption about the rationality of the use of approximation formulas for calculation of functions of mutual influence at minor ratios P/R.

The results of studies on the proposed method of calculation showed that at $0 \le P/R < 3$ it is expedient to use the dipole approximation to calculate the coefficients of the SLAE matrix and also aerodynamic loads, of the calculation of the spatial position of the vortex sheet. At the same time the accuracy of the calculation results are not worse than $0 \le P/R \le 1{,}5$. In the case when $\frac{P}{R} > 1$ it is recommended to conduct a double-precision calculation.

2.1. Checking the efficiency of the methods of calculation

Figure 2 shows the dependence of the calculating error $\delta(\bar{r})$ of SLAE matrix coefficients with the dipole approximation in comparison with the calculation performed with double precision, from the distance $\bar{r}$ to the vortex frame:

$$\delta = \frac{|w_2 - w_Д|}{w_2}, \tag{2}$$

where w_2 and $w_д$ - coefficients of the SLAE, calculated with double precision and using the dipole approximation.

The distance from an arbitrary point in space to the vortex frame is presented in relative units:

$$\bar{r} = \frac{r}{l}, \tag{3}$$

where l - length of the perimeter of the vortex frame.

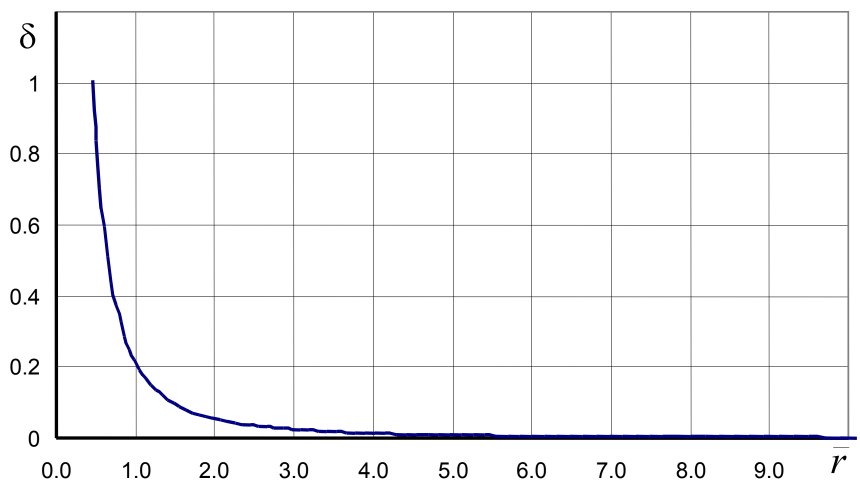

Figure 2. Dependence of the calculating error of SLAE matrix coefficients with the dipole approximation in comparison with the calculation

Dependence analysis $\delta(\bar{r})$ allows us to make a conclusion that at a distance from the computational point to the vortex frame $\bar{r} \ge 3$ calculating error is $\delta \le 5\%$.

2.2. Validation of the obtained results

For the validation of the obtained results of calculation of aerodynamic characteristics using the dipole approximation, numerical experiment with use of mathematical model of a rectangular wing was performed ($\lambda = 5$, $\alpha = 10^{\circ}$), the results of which were compared with those obtained by traditional methods that being used in discrete vortex method (DVM) [1].

Figure 3 shows the relative rate of calculation $\overline{T}$ of one pitch on the non-dimensional time, which was estimated using the expression:

$$\overline{T} = \frac{T_1}{T_2}, \tag{4}$$

where T_1 - rate of calculation using the dipole approximation, T_2 - rate of calculation according to adopted methods in DVM.

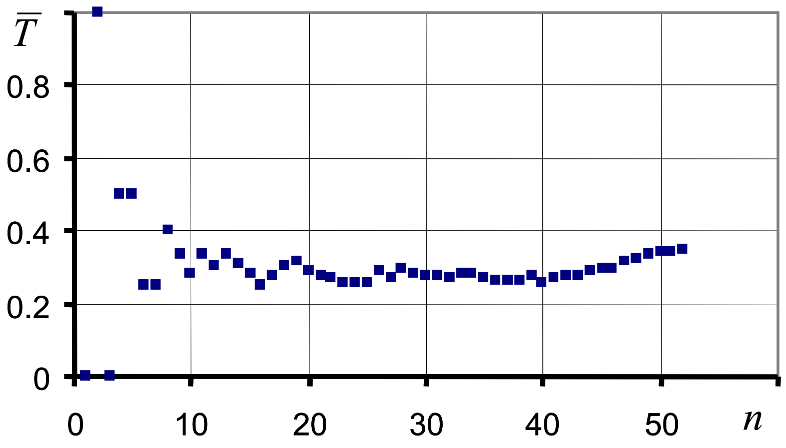

Figure 3. Relative rate of calculation depending on the pitch (on the non-dimensional time)

You can see that the rate of calculation using the dipole approximation, about 3 times higher than the rate for the calculation methods adopted in DVM.

The estimation error of the calculation of aerodynamic characteristics was performed. Figure 4 shows the dependence of the calculating error δ_{Cy_a} on the pitch on the non-dimensional time n, which was estimated by the formula:

$$\delta_{Cya} = \frac{\left| c_{ya2} - c_{ya1} \right|}{c_{ya1}}. \tag{5}$$

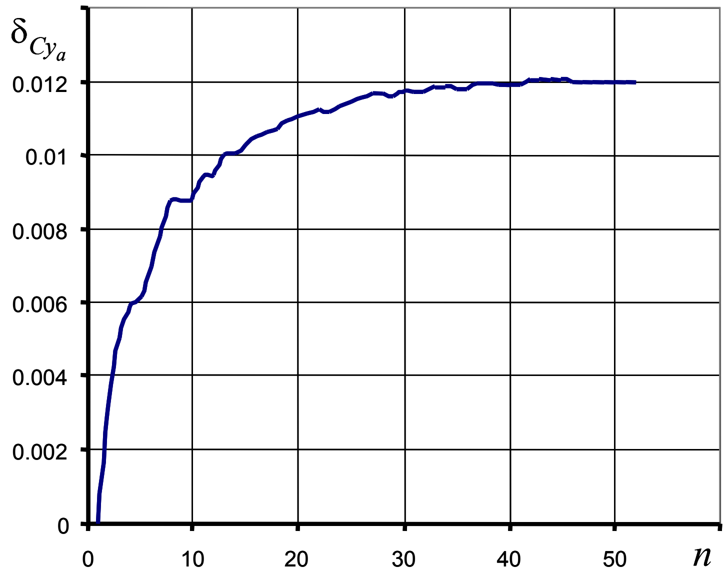

Figure 4. Dependence of the calculating error on the pitch
(on the non-dimensional time)

Analysis of dependence (Figure 4) shows that the calculating error of aerodynamic loads does not exceed 1.2%, which is quite acceptable for problems of this kind.

Figure 5 shows the dependence of the relative number of vortex frames for which elements of the SLAE matrix was calculated with double, single precision, as well as using the dipole approximation.

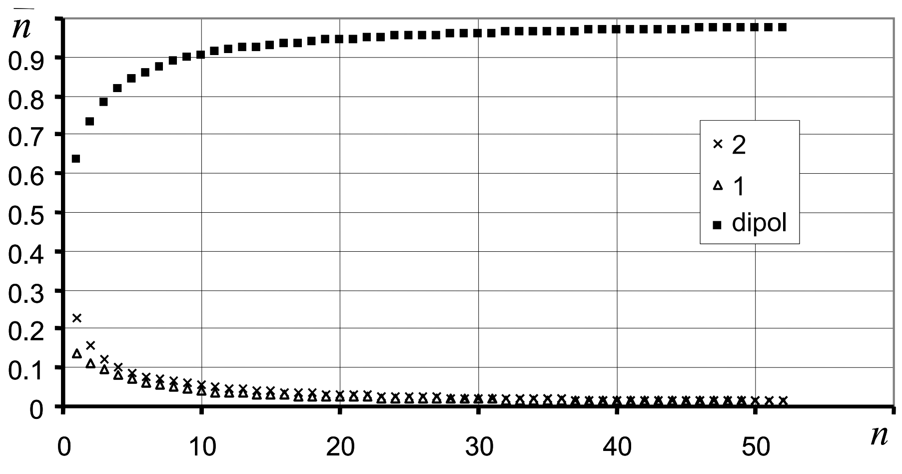

Figure 5. Dependencies of the relative number of vortex frames on the pitch
(1 - single precision; 2 - double precision)

Figures 6 and 7 shows similar dependencies for a rectangular wing ($\lambda = 5$, $\alpha = 60^{\circ}$).

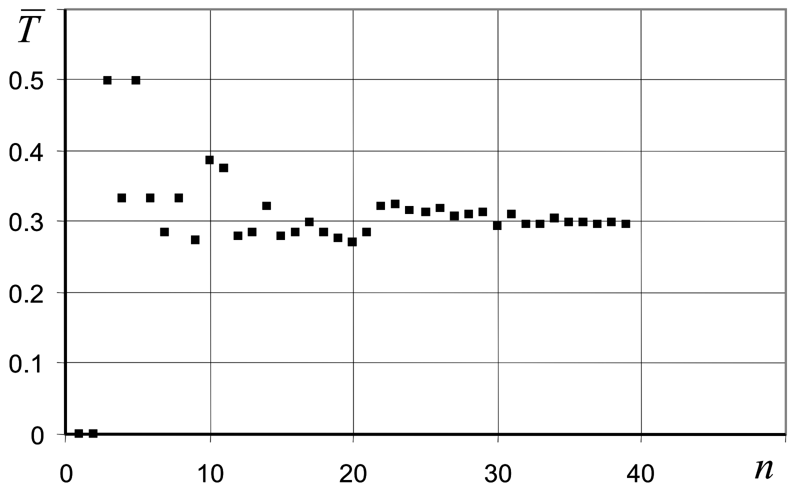

Figure 6. The relative rate of calculation of characteristics of rectangular wing depending on the pitch (on the non-dimensional time)

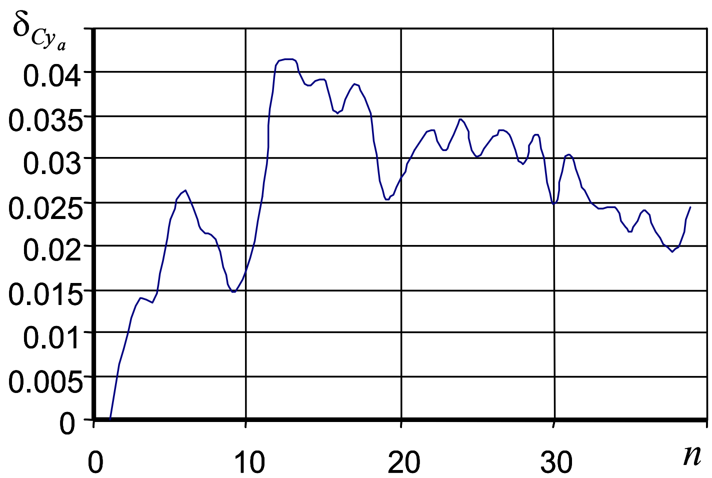

Figure 7. Dependence of the calculating error of the parameters of a rectangular wing on the pitch (on the non-dimensional time)

3. Conclusion

The considered approach of determining aerodynamic characteristics of studied objects by using discrete vortex method reduces the calculation time. The estimates calculating error of aerodynamic characteristics do not exceed 1.2%, which is quite acceptable for problems of this kind.

The analysis of the submitted dependences allows us to make a conclusion that the considered approach to the calculation of the functions of the mutual influence on the stages of SLAE formation, position of vortex sheet nodes as well as aerodynamic loads reduces hardware costs about three times, with a relative error of less than 4%.

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USE OF A PHASE TRANSITION CONCEPT FOR TRAFFIC FLOW CONDITION ESTIMATION

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The article covers the main models of traffic flow conditions, analyzes the condition estimation criteria, and provides the classification of models. The article provides the grounds for the use of the phase transition concept for traffic flow condition estimation. The models of the aggregate condition of free and congested traffic have been developed, the phase boundaries between free and congested traffic have been defined. Applicability conditions for the models of the aggregate condition of have been analyzed.

Keywords: traffic flow, classification condition, phase transitions

1. Introduction

The development transit networks projects should include the influence of network configuration on the efficiency of transit traffic [1]. Road network reconfiguration makes an impact on the characteristics of the traffic flow. The dependencies of transportation efficiency on the traffic flow parameters have been analyzed in numerous studies. To reflect these dependencies, the concept of traffic flow condition is used in the studies. Traffic flow condition is a highly aggregated qualitative characteristic of a traffic flow. Every traffic flow condition is associated with a certain level of economic efficiency of transportation, convenience from a driver's point of view, traffic safety, etc. The existence of traffic flow qualities is proven by experimental data [2, 3, 4, 5, 11].

The qualities are sorted out on the basis of quantitative evaluation of a traffic flow according to certain criteria. The issues of traffic flow condition estimation have been analyzed in many studies by Russian and foreign authors. The present article covers the applicability of a phase transition concept for traffic flow condition estimation.

2. Traffic flow condition models and their classification

Different models, which can be grouped according to different properties, are used for the estimation of traffic flow condition. For example, depending on the number of traffic flow parameters that are used as traffic flow condition estimation criteria, single-criterion and multi-criteria models can be defined.

The advantage of the single-criterion traffic flow condition models consists in the simplicity of the estimation. However, these models cannot always adequately represent the real situation on the road. For this reason, multi-criteria models that suppose the comprehensive evaluation of a traffic flow condition on the basis of a combination of traffic flow parameters, are seen as more efficient for practical tasks. These models enable to take into consideration the reciprocal influence of multiple parameters on the flow condition. In fact, multi-criteria models broaden the range of traffic flow condition. The number of these conditions can increase depending on the number of the criteria that have been used for the evaluation. In multi-criteria models the influence of a parameter evolution is geared to the evolution of other parameters.

One of the most widely used models is the single-criterion model, «*congested – non-congested traffic*». In other studies, the following similar terms are used for the same model: «forced traffic – free traffic», «steady mode – unsteady mode», etc. The main criteria that enables to define such condition is traffic flow density. Once traffic flow reaches a certain density, the car speed is no longer defined by a driver's strategy – instead, it starts to be determined by the shared general conditions that are typical for congested traffic.

In theory, the average car speed in «non-congested traffic» is limited by the restrictions caused by road factors. Determinate (descending) functional dependency of average speed, υ, on the flow density, ρ, is typical for congested traffic. In modern conditions and in the context of intense automobilization, numerous studies cover the dependencies of traffic flow parameters establishment in congested traffic.

In some single-criterion models traffic flow condition is treated as a function of road workload. Depending on the use of road capacity (workload), B. Beukers has determined three conditions: *steady flow*, *unsteady flow*, *forced traffic* (see Figure 1). The calculations have been performed for a road with the capacity of 2 000 cars per hour in one lane [6].

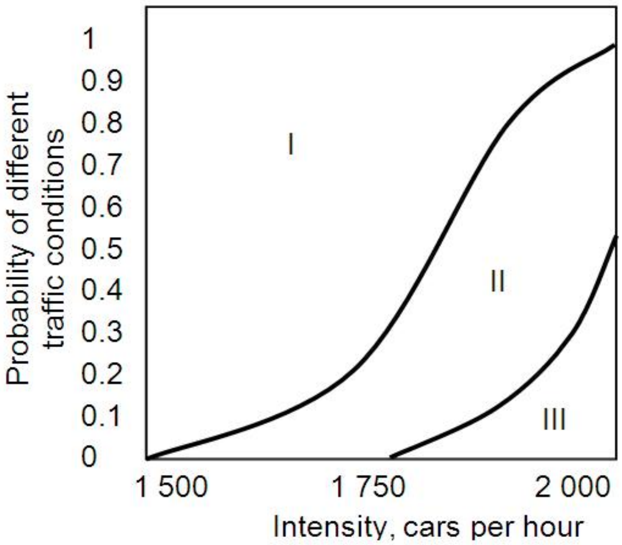

Figure 1. Relation between the intensity of flow intensity and traffic conditions:
I – steady flow;
II – unsteady flow;
III – forced traffic

Under the 75% load (with the intensity of 1 500 cars per hour), the traffic flow starts to become unstable. As far as the intensity increases, the instability grows. The probability of an unsteady flow is 50% under 90% load. With 2 000 light motor vehicles per lane, forced traffic emerges with a 50% probability.

The most valuable part of this single-criterion model is the *multidimensional representation* of a traffic flow condition. In other words, in this case, the transition from one flow condition to another is defined not only by the change in traffic intensity, but also by the probability of every condition for each level of traffic flow intensity. For example, under high traffic intensity (2 000 cars per hour) any of the traffic flow condition (steady, unsteady, forced traffic) can occur with the following probabilities: 0.5 for forced traffic, 0.45 for unsteady traffic, 0.05 for steady traffic. Possible conditions form a set of exhaustive events.

The quality of a traffic flow is also characterized by six so called “service levels“, depending on the type of the road, road capacity usage and actual speed [6].

For each service level, a traffic speed range for corresponding traffic intensity interval is defined. Within this problem statement, the model of service levels is a multi-criteria model. A service level is defined by the intensity and the average speed of traffic, which, in turn, is treated as a function of the flow intensity.

«Traffic convenience level» model, developed by V.V. Silyanov [3], also belongs to multi-criteria models. According to his data, every convenience level is characterized by certain drivers labor conditions, comfort and efficiency of transportation, as well as a certain accident rate.

Driving convenience levels are defined depending on the values of load, speed and traffic saturation level coefficients. On the whole, 4 traffic convenience levels are defined: «free», «partially bound», «bound» and «congested (saturated)».

The class of multi-criteria concepts conditions of traffic flow comprise Kerner's theory three phases in which the flow condition is characterized by the intensity and speed. Besides phase free traffic flow Kerenr distinguish in phase congested traffic two phases: synchronized flow and wide moving jam, and explains the mechanisms of transition between them [12].

«Traffic convenience level» flow condition model provides a more comprehensive reflection the of qualitative changes in the flow that are caused by the mutual influence of basic flow parameters. Exemplifying classification of the aforementioned models is shown at Figure 2.

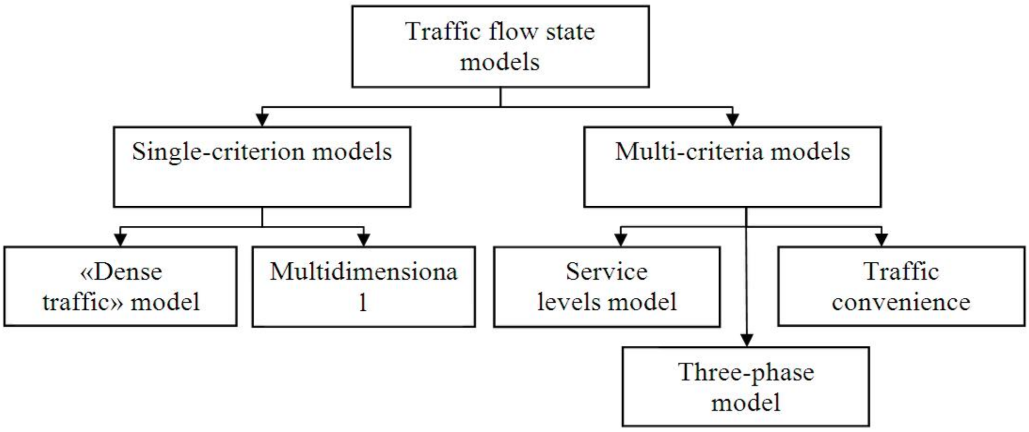

Figure 2. Classification of traffic flow condition estimation models

3. Phase transitions for traffic flow conditions

Formation of the flow qualities can be represented as phase transitions where continuous traffic flow condition changes being figuratively divided into several discrete (phase) conditions that form a phase space [7, 11].

During a phas e transition, a condition (phase) of a traffic flow changes due to the change in external conditions – that is, intensional parameters (i.e. density, distance, etc.) transmit the phase line. A step change in extensional parameters (i.e. speed, traffic intensity, etc.) occurs in the phase-transition point. As long as the phases are described by different equations of condition, it is always possible to find a value that changes stepwise during the phase transition.

Phase transitions of the first and the second kind can be defined. *A phase transition of a first kind* implies the change of *the aggregate condition of the system*. In this case, either the essential parameters of the system change stepwise, or the operation principles of the system change. The following two *aggregate* conditions of a traffic flow are defined: *free and congested traffic*. Each condition can be characterized through the possible choice of road speed. In *free traffic,* a driver can choose convenient speed, υ_e – «free» speed (so called «desired» speed). This speed approximates the maximum possible speed ($\upsilon_e \approx \upsilon_{\max}$) under given traffic conditions: safe speed for a single car, speed limit defined by traffic rules, technically possible speed, etc. In heavy traffic, the speed υ_e is limited by the flow parameters (i.e. high flow density or heavy traffic, etc.), so the drivers choose the average speed of the flow ($\upsilon_{\mathrm{e}} \approx \upsilon'_{\mathrm{e}}$) that can be significantly lower than the maximum possible speed ($\upsilon'_{\mathrm{e}} < \upsilon_{\max}$) [8].

Phase transitions of the second kind are considered to be inappreciable to an unaided eye and to occur within the limits of the *aggregate* conditions. Stepwise changes can occur, for example, in first order derivatives of extensive characteristics, for example, first derivative of speed is acceleration or deceleration. Phase changes of the second kind can be found in the traffic flow conditions for free and congested traffic. For example, the phase conditions can be determined in free traffic depending on the braking of a car if a car ahead has used emergency braking.

The transition between the *aggregate* conditions is related to the limitation of speed by flow factors. Traffic speed is a determined (descending) function of a flow density: $\upsilon_e = \upsilon_e(\rho)$. With maximum flow density, $\rho_{\max,}$ traffic is blocked, in other words, $\upsilon_e(\rho_{\max}) \approx 0$.

In accordance with the statements of follow-the-leader theory, all drivers adapt their speed, $\upsilon_{n,}$ to the speed of the leader, $\upsilon_{n-1,}$ while keeping the safe distance (depends on the speed) to the leader car $d_s(\upsilon_e)$ [9].

The distance between the cars can be represented through the flow density:

$$d_\rho = d_e + d_{\min} = 1/\rho - l_a, \quad (1)$$

where d_e is a dynamic distance; $d_{\min}$ is the minimal distance for maximum flow density; l_a being the average car length in traffic.

For the maximum flow density, $\rho_{\max,}$ the safe distance is $d_s = 0$, because the speed $\upsilon_e = 0$. In the first place, the increase of ρ (flow density) leads to the decrease of maximum possible dynamic distance between cars (d_e) to the value defined using (1) minus $d_{\min}$:

$$d_e = d_\rho - d_{\min}, \quad (2)$$

and, consequently, to the possible decrease of safe distance (d_s) and, as a consequence, to the possible limitation of car speed in traffic (υ_e) not by the maximum speed ($\upsilon_{\max}$), but the safe speed (υ_s) with current safe distance: $\upsilon_e \le \upsilon_s(d_s)$. By the data, $\upsilon_s \le \upsilon_{\max}$.

This being said, the speed (υ_e) may not decrease, if the dynamic distance is not lower than safe distance for the speed, υ_e: $d_e \ge d_s(\upsilon_e)$. Safe distance can be calculated according to the formula:

$$d_s \ge \upsilon_e\, \tau + \Delta l_m + d_{\min}. \quad (3)$$

where τ is the time of the reaction on the braking of a leader car; Δl_m is the difference between the braking distance of the front and the rear car.

The study [2] considers some additional factors in the calculation of the distance, which are related to the perception of road events by the drivers, for example, the driver's sensitivity to the change of the leader's speed. These factors present some features of interest, as the congested flow traffic observations show that the majority of cars are moving with the lesser distance than is calculated according to (3). Moreover, the difference between the actual distance and the distance that was calculated using (3), increases as far as the traffic speed increases.

4. Mechanism of phase transitions between traffic flow conditions

Phase transitions between the flow conditions are caused by the establishment mechanism of car speed, $\upsilon_{e,}$ as a function of the flow density. Dynamic distance between the cars cannot exceed the distance defined by the flow density conditions ($d_e < d_\rho$), and the safe distance should not exceed the dynamic distance ($d_s \le d_e$):

$$d_s \le d_e < d_\rho. \quad (4)$$

For every $\upsilon_{\max}$ value, there is a safe distance $d_s(\upsilon_{\max})$ calculated according to (3). The condition, $d_s(\upsilon_{\max}) > d_e$ means that the distance $d_s(\upsilon_{\max})$, which is necessary for maximum speed, cannot be reached in accordance with the flow density conditions. For this reason, maximum safe distance, d_s, is defined not by the speed in accordance with (3), but by the flow density in accordance with (2). Subsequently, maximum possible speed, υ_e will be limited by υ_ρ, which complies with the safety requirements in case of $d_s = d_e$ and is defined by the expression (3).

Limitation mechanism for the flow speed, υ_e, is shown at the Figure 3, where the following graphics of monotonous functions are presented: d_s is increasing function by speed, d_e is decreasing by density. Maximum density, $\rho_{\max}$ can be defined using (1) if $\rho = \rho(d_\rho) = \rho\,(0)$.

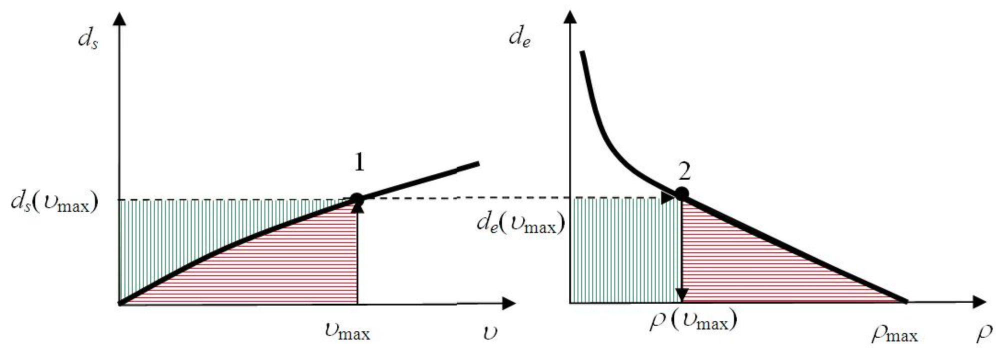

Figure 3. Establishment mechanism for traffic flow characteristics and conditions

If road conditions allow the traffic speed to be equal υ_{max}, then, for safe driving at this speed, the distance $d_s(\upsilon_{max})$ should be kept – see point 1 (Figure 3). The condition (4) implies that this distance should not exceed the distance $d_s(\upsilon_{max}) \leq d_e(\rho_e)$ that is defined by the flow density – see point 2. Distance defined by density, $d_e(\rho_e)$ will be kept if the flow density does not exceed ρ_e. For this reason, the flow speed can reach the υ_{max} value if the flow density at the section equals $\rho = (0, \rho_e)$. Hatched area shows the ρ value that enables the driving with υ_{max} speed. At the corresponding section, the flow condition is defined as free traffic.

The flow density increase at the section: $\rho = (\rho_e, \rho_{max})$ leads to the decrease of maximum possible speed, υ_{max}, which is set with regard to the limitation caused by the road factors. Flow condition for $\rho = (\rho_e, \rho_{max})$ is defined as congested traffic.

Phase condition diagram of traffic flow conditions is shown at Figure 4. Driving distance d_e is considered to be the main intensive parameter. Traffic speed υ_e is considered to be the extensive parameter.

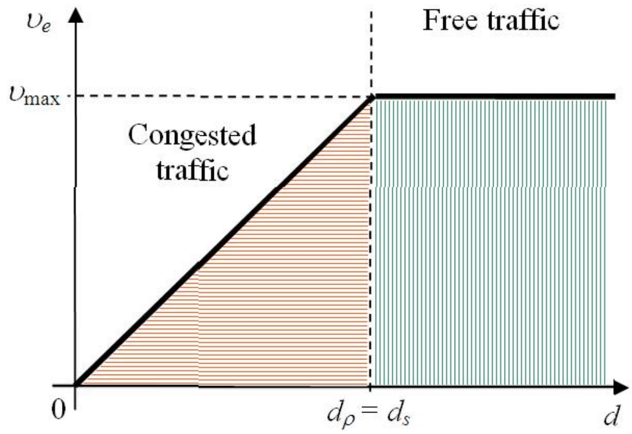

Figure 4. Phase condition diagram of traffic flow conditions

The diagram shows the aforementioned rules for phase transitions between traffic flow conditions. In the congested traffic area, the following condition is met: $d_\rho < d_s$. Consequently, the flow speed, υ_e is limited by the distance defined by density and is less than the maximum speed, υ_{max}, which is defined by the road conditions. When the distance defined by the flow density d_ρ increases, the speed can also be increased if the road safety conditions are met (increasing function). In the free traffic area, the following condition is met: $d_\rho > d_s$. For this reason, the flow speed is limited by the possible road conditions, υ_{max} = const (straight line).

It is worth mentioning that the phase diagram is similar to sectionally continuous Grinberg function, «speed – density», is shown at Figure 5 [10]. In accordance to this function, the flow moves «freely» with the average speed of $\upsilon_{св}$ at a low density section $(0, \rho_a)$. When the density increases $(\rho_0 > \rho_a)$, traffic speed starts to decrease, and for maximum density ρ_{max} the flow movement is impossible ($\upsilon = 0$).

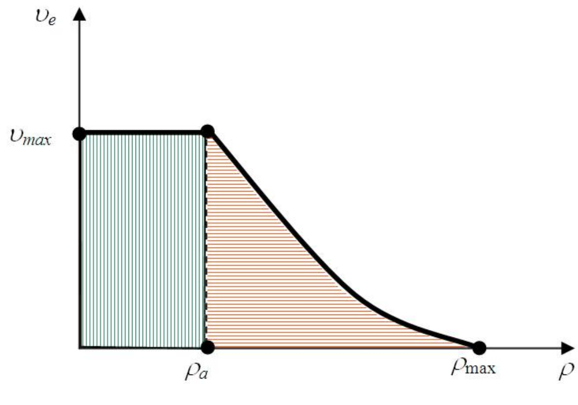

Figure 5. Greenberg's model

5. Model of the aggregate conditions of matter for a traffic flow

The indicators of the flow conditions are: maximum possible speed under given road conditions, $\upsilon_{\max}$, (is the limitation of the flow speed, υ_e); flow density, ρ, which is defined by experiment or by calculation; safe distance, d_s, which is calculated using (2); distance defined by the flow parameters, d_ρ, which is calculated using (1).

Aggregate condition of free traffic. It shall be assumed that the traffic flow is in the free movement condition if the cars can move with the maximum speed possible, $\upsilon_{\max}$. This condition is true for a particular flow density value, ρ, which makes the following inequality valid: $d_e \geq d_s(\upsilon_{\max})$.

Aggregate condition of congested traffic. The increase of ρ leads to the decrease of d_e. As soon as the relation between the distances change ($d_e < d_s(\upsilon_{\max})$), traffic speed, υ_e, will be limited by the flow factors. The condition of the flow will change from free traffic to congested traffic.

In free traffic, the limit of the flow speed increase is defined by the $\upsilon_{\max}$ (limited by the road factors), in congested traffic the speed, υ_e is set at the level that guarantees safe traffic conditions for the distance that is limited by density, d_e (limited by the flow factors):

$$\upsilon_e = \begin{cases} \upsilon_{\max}, & \text{if } d_s \leq d_e \\ \upsilon_\rho, & \text{if } d_s > d_e \end{cases}. \tag{5}$$

This model generally characterizes the formation conditions for the conditions of homogeneous flow as a system in equilibrium. For this system, the identity of all its dynamic characteristics (density, speed, distance, etc.) holds true at a certain section of the road. It is usually considered that such properties are atypical for real conditions. In addition, the homogeneous properties of the flow are observed in congested traffic and heavy load, when all vehicles are moving with equally low speed, keeping small distance between the vehicles. The properties of a homogeneous flow are observed at the multi-lane roads, in particular, with two lanes for each direction, where the laminar effects are observed with the distribution of the cars along the lanes with regard to optimum speeds.

For this reason, phase transition model can be used with further modification in the light of specific features of traffic flow movement in particular transport networks.

6. Conclusion

Revealing the conditions of a traffic flow is highly important to estimate the measures taken to augment the transit potential of transport systems. To increase the speed of transit traffic in free traffic conditions, the roads can be broadened, the road surface can be repaired, etc. To increase the traffic speed in congested traffic, transport network reconfiguration should be considered.

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OIL POLLUTION IN THE SOUTHEASTERN BALTIC SEA IN 2009-2011

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From January 2009 to April 2012 a satellite survey of the central and southeastern parts of the Baltic Sea was carried out by the Space Radar Laboratory at the Space Research Institute of Russian Academy of Sciences (RAS). The main attention was focused on the detection of oil pollution as well as biogenic and anthropogenic surfactant films. The basic data are high resolution radar images obtained by advanced synthetic aperture radar (ASAR) on board of the Envisat satellite of the European Space Agency. Remotely sensed data in visual and infrared (IR) bands acquired by sensors MERIS Envisat, MODIS-Terra and –Aqua, and AVHRR NOAA nearly simultaneously with the ASAR images, were processed and analysed in order to facilitate the discrimination between different types of surface pollutants, to understand a comprehensive features of meteorological and hydrodynamic processes in the sea area of investigation, and to reveal factors determining pollutants spread and drift. The regions of the most intense oil pollution are outlined.

Keywords: Southeastern Baltic Sea, oil pollution, satellite monitoring, synthetic aperture radar, Envisat, MODIS-Terra and Aqua

1. Introduction

In recent years a number of new oil terminals have been built in the Baltic Sea area, resulting in increased transport of oil by ships and, consequently, an increased risk of accidents (Kostianoy and Lavrova, 2014a). Transportation is a reason of 45% of the oil in the sea while an offshore production is a source of only 2% of the oil pollution in the World Ocean. In the Baltic Sea about 2,000 large ships and tankers are at sea every day (Global Marine…, 2012). Thus, shipping activities, including oil transport and oil handled in harbours, have major negative impact on the marine environment and coastal zone in the Baltic Sea (Kostianoy and Lavrova, 2014a).

Public interest in the problem of oil pollution arises mainly during dramatic tanker catastrophes (Kostianoy and Lavrova, 2014b). The catastrophic oil spills are quite rare and caused, generally, by tanker crashes, as a rule, such events are broadly covered by mass media. Much less attention is paid to oil contamination of the sea surface caused by routine activities on ships. Ship-related operational discharges of oil include: (i) discharge of bilge water from machinery spaces; (ii) operational discharges of oil from machinery spaces to the sea; (iii) discharge of tank-washing residues and oily ballast water.

Oil and oily residue discharges from ships represent a significant threat to marine ecosystems. These discharges may occur during normal activities or may be accidental or illegal. Oil spills cause the contamination of seawater, shores, and beaches, which may persist for several months and even years (Kostianoy and Lavrova, 2014c).

As concerns oil exploitation at sea and on the coast, offshore operations have been taking place for some years in Polish waters (two jack-up rigs); until recently Germany operated two platforms very close to the coast; in March 2004 Russia started the oil production at continental shelf in the waters between the Kaliningrad area (Russian Federation) and Lithuania, as well as there are Latvian plans to drill for oil in the waters between Latvia and Lithuania (Global Marine…, 2012). So far as the Baltic Sea ecosystem undergoes growing human-induced impacts, especially associated with an increasing oil transport and production, one of the main tasks in the ecological monitoring of the Baltic Sea is an operational satellite and aerial detection of oil spillages, determination of their characteristics, establishment of the pollution sources and forecast of probable trajectories of the oil spill transport.

The authors of the present paper have the ten years experience in satellite monitoring of the Baltic Sea which includes three stages:

I. In June 2003 LUKOIL-Kaliningradmorneft (Kaliningrad, Russia) initiated a pilot project, aimed to the combined monitoring of the southeastern Baltic Sea, in connection with a beginning of oil production at continental shelf of Russia in March 2004. Operational monitoring was performed in June 2004 – November 2005 on the base of daily satellite remote sensing (AVHRR NOAA, MODIS, TOPEX/Poseidon, Jason-1, ENVISAT ASAR and RADARSAT SAR imagery) of sea surface temperature (SST), sea level, chlorophyll concentration, mesoscale dynamics, wind and waves, and oil spills (Kostianoy et al., 2005, 2006, 2014).

II. Starting from 2009 up to the April 2012 a satellite survey of the central and southeastern Baltic was carried out by the Space Radar Laboratory at Space Research Institute of Russian Academy of Sciences (RAS). The main attention was focused on the detection of oil pollution as well as biogenic and anthropogenic surfactant films (Mityagina et al., 2012; Kostianoy et al., 2014a).

III. In 2010-2013 daily satellite monitoring of construction and exploitation of marine gas pipeline “Nord Stream” in the Gulf of Finland was carried out by the Ocean Experimental Physics Laboratory at P.P. Shirshov Institute of Oceanology of RAS. It was focused on the suspended matter and oil pollution in the area of the pipeline construction, as well as on the detection of different effects, related to the exploitation of the pipeline, in the sea surface temperature (SST), suspended matter, chlorophyll concentration, sea surface roughness, and sea ice fields (Grishin and Kostianoy, 2012a,b; 2013; Kostianoy et al., 2014b).

In this paper we will refer on the results obtained during stage II, which basically remained unpublished in English editions.

2. Tasks and technical means

The main attention was focused on the detection of anthropogenic and biogenic surface films. Four main types of sea surface polluting films were investigated, caused by: (i) oily wastewaters discharged by watercrafts; (ii) sewage discharge, river and coastal outflows, containing anthropogenic and natural pollutants; (iii) increased biological productivity, including chlorophyll life cycle and intensive algal bloom.

The surface pollution and sea dynamics monitoring was based on receiving; processing and combined analysis of satellite imagery obtained by various sensors installed on different satellites and operating in different bands of electromagnetic waves. The basic data were high resolution radar images obtained by synthetic aperture radars (SAR) ASAR Envisat and SAR ERS-2. The SARs are the most important devices for satellite monitoring of the sea surface condition and for pollution level assessment due to the following reasons: (i) twenty-four-hour operation capacity, image parameters being independent on solar illumination; (ii) radar measurement can be performed under any weather conditions, as the atmosphere is nearly transparent for SAR microwave radiation; (iii) dielectric property of water at microwave frequencies is homogeneous, and the fluctuation of scattered signal is induced solely by parameters of sea surface roughness which facilitates satellite imagery interpretation; (iv) high spatial resolution of advanced space SAR permits detecting even insignificant oil pollution with required accuracy.

Nevertheless, detection of the sea surface oil pollution based only on SAR data is rather problematic because of the difficulty in distinguishing oil slicks, especially at lower wind speeds, from other phenomena known as oil "look-alikes" (Espedal and Johannessen, 2000; Brekke and Solberg, 2005). The wave damping may be related not only to oil films, but also to biogenic films, land-shadowed areas near coasts, rain cells, zones of upwelling, young ice, and oceanic or atmospheric fronts (Espedal and Wahl, 1999). The contrast between a spill and surrounding water, and therefore the probability of detecting pollution films, depends both on the amount and type of oil as well as on environmental factors such as wind speed, wave height, SST, currents and current shift zones.

The discrimination of anthropogenic and natural (biogenic and mineral) films is one of the most difficult tasks. Our experience gained from a number of monitoring campaigns shows that this problem can be successfully solved on the base of combined use of satellite data taken in visual, IR, microwave ranges, and oceanographic and meteo information (Lavrova et al., 2011). This data is obtained by different sensors mounted on board of different Earth observation satellites. The key problem consists in combining data varying in physical, spatial, temporal resolution and image dimension.

The technology of multisensor satellite monitoring of the sea surface was developed and tuned by a consortium of research teams, including the research groups from Space Research Institute, P.P. Shirshov Institute of Oceanology, Geophysical Center of the Russian Academy of Sciences, and Marine Hydrophysical Institute (Kostianoy et al., 2005; 2006; 2007; 2014a; Shcherbak et al., 2008; Lavrova et al., 2009; 2011).

Data in visual and IR bands taken by MERIS Envisat, MODIS Terra/Aqua and AVHRR NOAA nearly simultaneously with the ASAR images, were involved into consideration in order to facilitate the discrimination between different types of surface pollutants, to reveal the of meteorological and hydrodynamic processes in test areas, and to determine factors governing pollutants spread and drift. Supplementary data were obtained also from scanning radiometers ETM+ Landsat-7 and TM Landsat-5. Meteorological data, required for the analysis of satellite data, were provided by coastal meteo stations.

3. Basics of radar detection of the sea surface oil pollution

Satellite monitoring of oil pollution of the sea surface is based on the capacity of satellite-borne radars to reveal sea surface areas (so-called film slicks) covered by surface films. Surface films lead to reduced interaction of ocean waves and wind as well as to attenuation of the resonance gravity-capillary component of surface waves. In this case some smooth areas (slicks) appear on the sea surface and form areas of reduced backscattered signal in radar image which can be considered as indicators of the sea surface pollution (Alpers and Huhnerfuss, 1989; Jenkins and Jacobs, 1997; Mityagina and Churumov, 2006).

In the course of radar experiments there was investigated the correlation between radar backscattering contrasts, caused by an oil film covering the surface, and such parameters as sea surface waves, wind speed and direction, the condition of near-surface layer of atmosphere. As a result the optimal conditions for satellite pollution monitoring were specified, namely wind speed – 3-9 m/s, and wave heights – up to 1.25 m, stable stratification of the atmosphere – ocean boundary layer. Furthermore, the near-surface wind is the most important factor effecting the reliable detection of oil pollution on the sea surface via radar imagery (Gade, 2006). Under the wind speed exceeding 9-10 m/s both oil and biogenic polluting films cannot be discerned in radar images.

Under windless conditions or under weak unsteady winds the capillary-gravity component of the sea surface wave field may not develop. This results in attenuation of backscattered signal. Moreover, in radar images obtained under weak near-surface wind there are usually a large number of low backscatter areas that are not related to the presence of surface films. The existence of these low scattering (dark) areas in radar images increases the “false alarm” probability in oil pollution monitoring.

The contrasts between the spill area and the sea surface around it are determined by a number of parameters: wind speed, wave height, quantity and a type of spilled oil, etc. The shape of spill may vary depending on whether it was discharged by a moving or a stationary object.

It should be noted that the detection of oil spills in Baltic Sea area by means of satellite radar imagery is rather complicated due to unstable meteorological conditions. Complicate hydrometeorological conditions – too high or too low surface wind (calm sea, wind shadow), algal bloom, ice cover, intensive precipitation, passing by of atmospheric and wind fronts, atmospheric convection and atmospheric gravity waves – all this make difficult the detection and identification of spills.

The main factors making the detection of the surface manifestations of the internal waves in radar images difficult are the active atmospheric processes in this area resulting in considerable variation of the near-surface wind field. Of course atmosphere is transparent for radar signal and atmospheric processes are displayed in radar images only via inhomogenities of the gravity–capillary component of the sea-surface wave field. Resulted from mesoscale processes wind field variations modulate short gravity waves at the sea surface resulting in the inhomogenities of the backscattered radar signal distribution.

We found that imprints of atmospheric phenomena cover the major part of practically every radar image taken in this region, and the variations of radar signal intensity they introduce are rather high. Often it makes practically impossible to identify manifestations oily spillages at the sea surface.

4. Main results of satellite monitoring of the sea surface oil pollution

Fig.1 shows the cumulative map of oil spills revealed from satellite radar data in the southeastern part of the Baltic Sea during the time period from January 2009 till December 2011. It is possible to find out regions of most frequent discharges. They are:

(1) The main shipping route eastward of Gotland Island;
(2) Shipping routes to the Klaipeda and Liepaja ports;

(3) Area northward of the Hel Spit (Gdansk Bay);
(4) The part of Gdansk Bay in the vicinity to the entrance to Kaliningrad Canal.

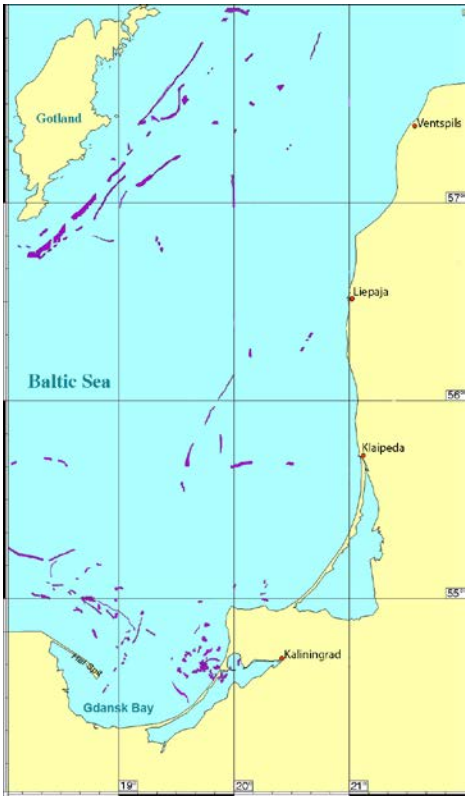

Figure 1. Map of oil spills revealed from satellite radar data in the southeastern part of the Baltic Sea in 2009-2011

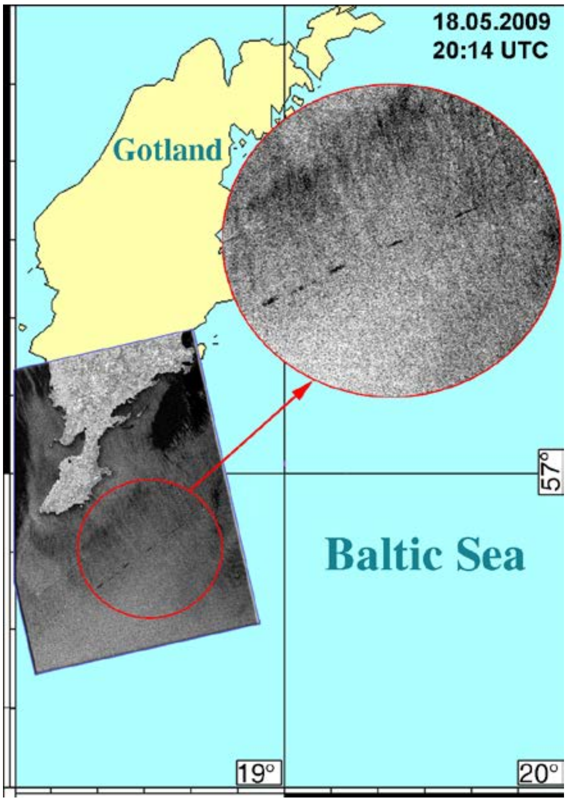

Figure 2. ASAR Envisat, 18.05.2009, 20:14 UTC. Oil spills chain. Total length - 30 km. Total surface – 5.1 km^2

The features of sea surface oil pollution revealed in radar imagery and typical for these regions will be discussed herein. We detected plenty pollution events along the main shipping route eastward of Gotland Island. All these events are caused by spillages of oil-containing waters from moving ships. These spillages appear as straight dark (reduced signal) stripe in radar image following the ship route leading from south-west to north-east. Some ships continue dumping wastewaters for dozens of kilometers on their way. Quite often ships discharge wastewaters several times while they are moving. Such examples are shown in Figs. 2 and 3. Fig. 2 shows a well-defined dashed spill of nearly 30 km long which ends by a bright point indicating the position of a moving ship. The spillage was conducted shortly before the radar image acquisition and the film has just started to spread, the closer to the ship the narrower the spill and one can observe high radar contrast between the spill area and the sea surface.

The example shown in Fig. 3 is characterized by wider film spreading under the influence of wind and waves and lower contrasts of the dashed spillage stretching for more than 50 km. The latter discharge took place a few hours before satellite pass over the area of interest and the responsible ship–culprit could not be found. Apparently spillage was produced in several stages. The total polluted surface area had reached 105 km^2 by the moment of radar image acquisition. This is the biggest spillage detected over the period of monitoring.

Wind has a great direct and indirect effect on the structure of a spill. Under the direct influence of the wind the film shifts over the sea surface, oil being accumulated on the leeward of the patch. Moreover, near-surface wind induces dynamic processes in the upper layer of the sea. The Lengmuir circulation is the most common process which is caused by wind driven spiral circulations of alternating directions with the axis almost parallel to the wind. Inside a vortex water moves in the plane perpendicular to the wind velocity vector. Thus on the sea surface there appear alternating divergence and convergence zones, oil being concentrated in the latter. An oil spill transforms into streaks that are referred to as “comb-like structure”. Such transformation of the spills left by a moving ship can be seen in Fig. 3.

Spillages detected in the radar images taken over the central part of the area of interest along the shipping routes leading to Klaipeda and Liepaja are characterized by lesser lengths and are less numerous.

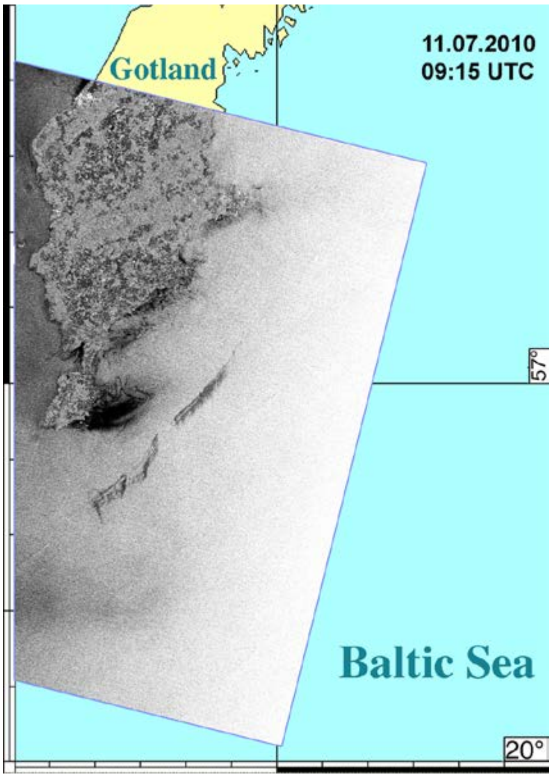

Figure 3. ASAR Envisat, 11.07.2010, 09:15 UTC. Weathered oil spills chain. Total length - 51 km, total surface – 105 km^2

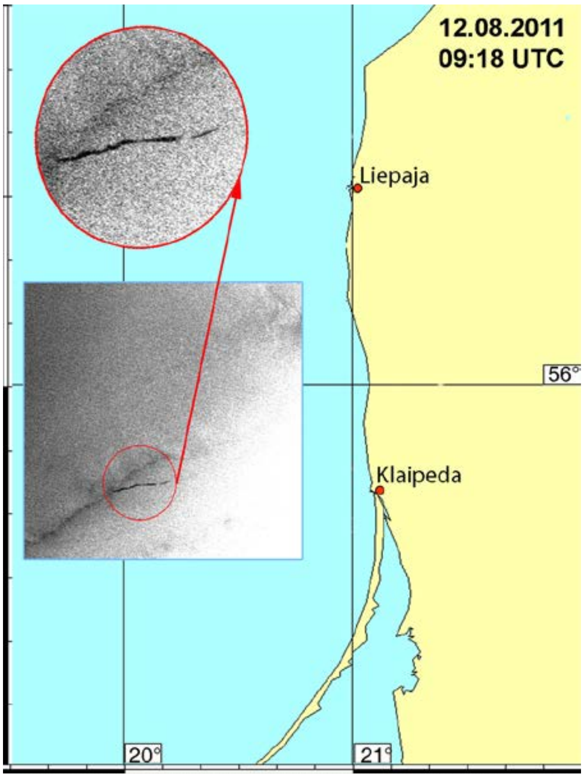

Figure 4. ASAR Envisat, 12.08.2011, 09:18 UTC. Oil spill from the moving vessel. Length – 12.5 km, surface - 6 km^2

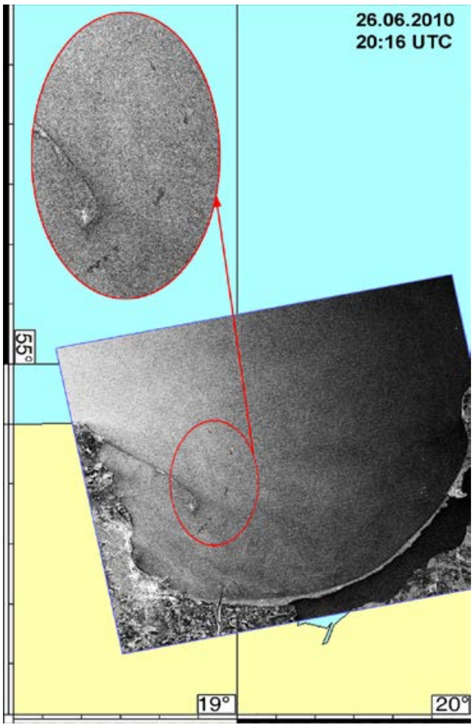

Figure 5. ASAR Envisat, 26.06.2010, 20:16 UTC. Multiple spillages from a moving ship Total length - 30 km, total surface – 6.8 km^2

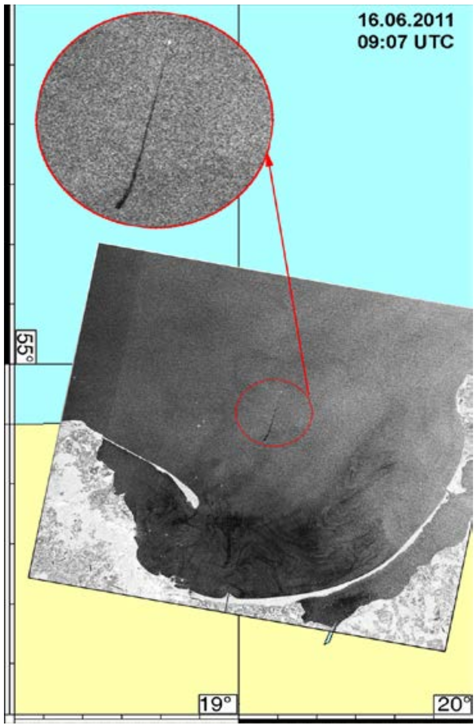

Figure 6. ASAR Envisat, 16.06.2011, 09:07 UTC. Fresh oil spill from a moving vessel. Length – 15.7 km

This may be due to the less intensive shipping traffic in this area. Many of detected pollution events were weathered oil spills characterized by wider film spreading and lower radar backscattering contrasts. A weathered spill of 12.5 km long left by a ship moving to/from the port of Klaipeda can be easily seen In Fig. 4. The spill shape is distorted due to local currents and near-surface winds and the narrowing of its most fresh part is not obvious. It is impossible also to identify explicitly a ship responsible for the spill.

Numerous spillages were detected in the Hel Spit area. Many of them have the form of enveloping curve duplicating the main shipping route leading from the port of Gdansk to southwestern ports of Baltic Sea and Dutch Straits and going round the Hel Spit. An example of this kind of spillages is shown in Fig. 5. It depicts a multiple spillage spread under the influence of winds and waves.

Other spillages in this area are stretched in north-eastern direction along the route leading to the ports of eastern Baltic. In Fig. 6 is given an "ideal" example of how fresh track of discharged wastes is depicted in a satellite image. The ASAR Envisat image a section of which is shown in the Fig.6 was taken in the area of Gdansk Bay under light wind and light sea surface disturbance.

The dark stripe depicting the spillage becomes narrower to north-east, which indicates that the ship - culprit discharged wastewaters moves in this direction. Bright image point in the north-eastern end of the stripe demonstrates the present locations of the ship. The wastewater stripe extends for 15.7 km.

Pollution events detected in Gdansk Bay near the Pilava Strait (Kaliningrad Canal) are quite different from the ones described before. The water contamination in this area is mainly caused by wastewaters containing oil dumped from motionless ships in the anchorage site. Large number of spills having relatively small areas is detected in this area regularly. An example of typical situation in this area is shown in Fig. 7. But sometimes oily films spread over a large area under the influence of near- surface winds and surface waves. This situation is shown in Fig. 8, the total polluted surface area is of about 30 km^2.

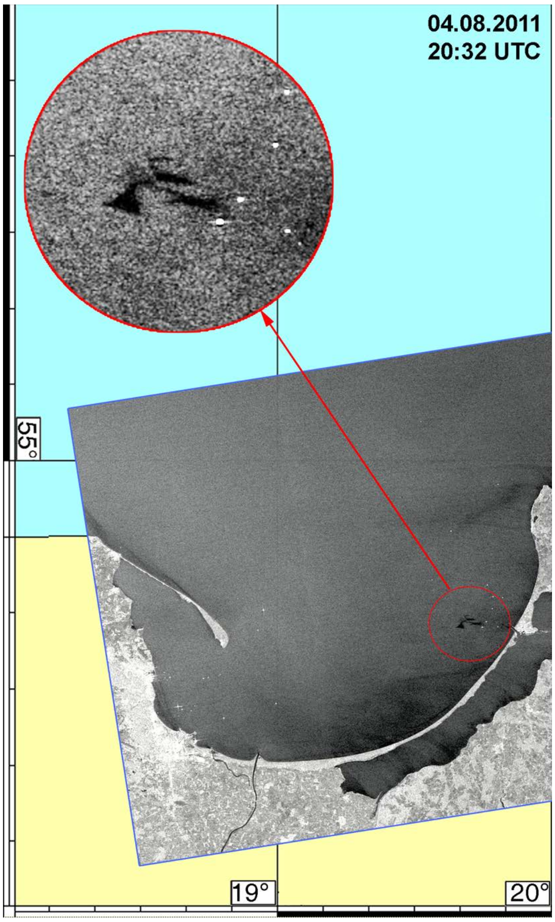

Figure 7. ASAR Envisat, 04.08.2011, 20:32 UTC.
Total surface – 4.64 km^2

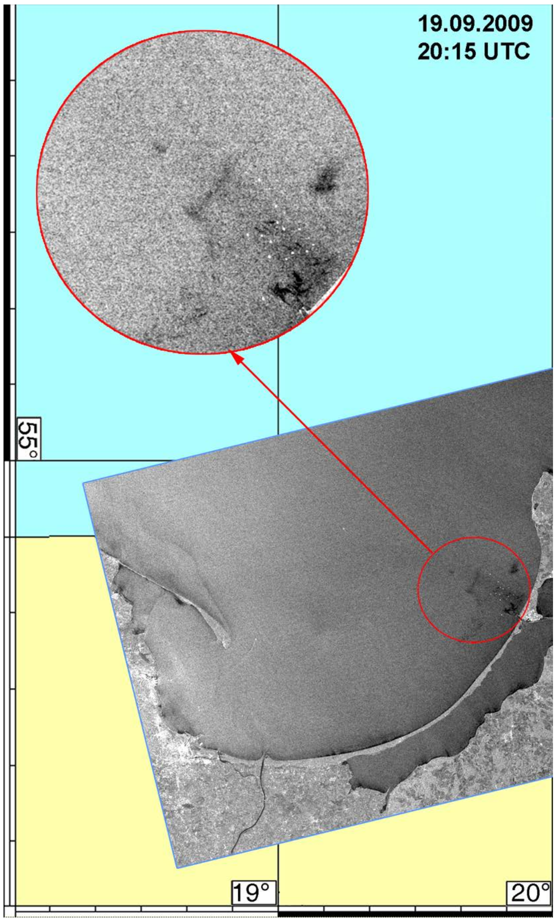

Figure 8. ASAR Envisat, 19.09.2009, 20:15 UTC.
Total surface – 31.4 km^2

5. Summary of oil spills in the southeastern Baltic Sea revealed from satellite SAR/ASAR data

Over three years of observation (2009-2011), 122 events of sea surface oil pollution as a result of ship discharges have been detected in the southeastern part of the Baltic Sea. Year-by-year numbers of oil spills are 37, 47, and 38, correspondingly. Total polluted areas are 150, 160, and 74 km^2. Individual oil spill areas varied from 0.1 to 105 km^2. Some statistics on oil spills in the southeastern part of the Baltic Sea revealed from satellite SAR data is shown below in Figs. 9-14. These are year-to year and average monthly numbers of spills detected in the southeastern Baltic Sea, numbers of spill revealed in different regions of the southeastern Baltic Sea over the three years of observations, annual size distribution of total area of the oil pollution, and total polluted areas for various regions of most intense pollution, described in this paper. Almost 75% of oil spills had a size less than 2 km^2 (Fig.14). Oil spills larger than 6 km^2 are quite rare.

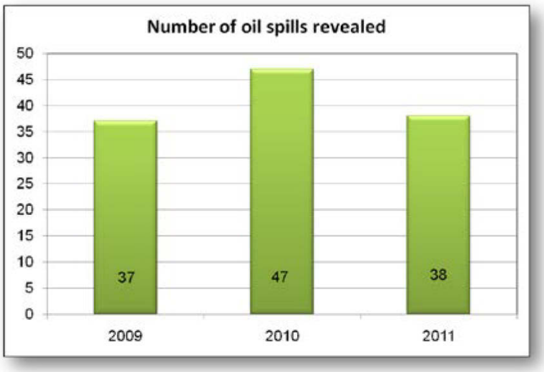

Figure 9. Year-to year distribution of a number of oil spills detected in the southeastern Baltic Sea

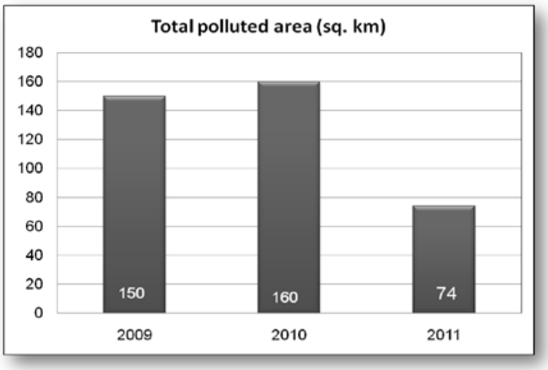

Figure 10. Year-to year total polluted area in the southeastern Baltic Sea

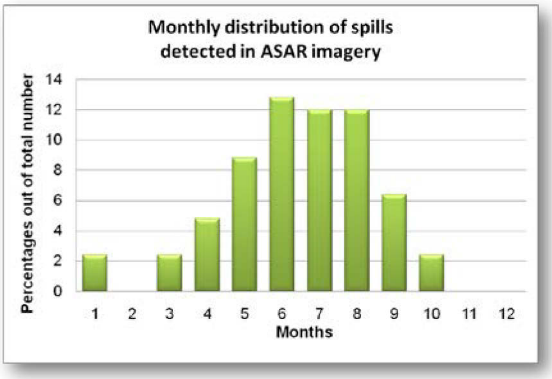

Figure 11. Seasonal distribution of oil spills detected in the southeastern Baltic Sea

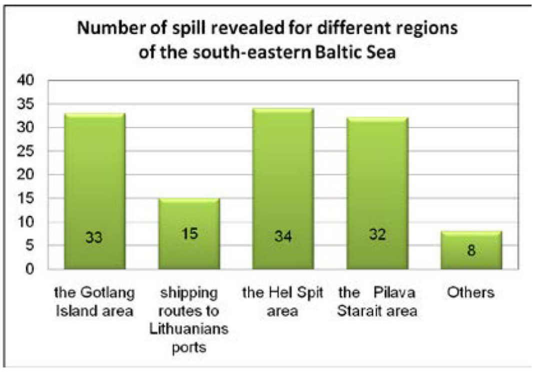

Figure 12. Total number of oil spills detected in different regions of the southeastern Baltic Sea

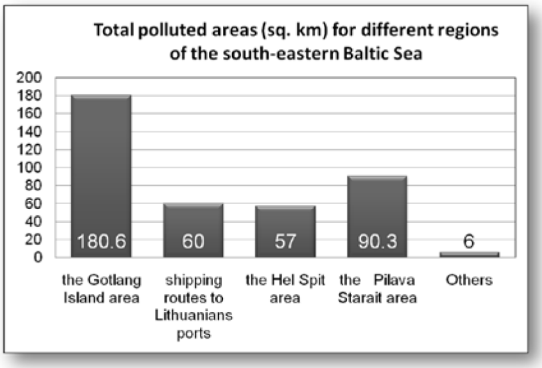

Figure 13. Total polluted areas (km^2) for different regions of the southeastern Baltic Sea

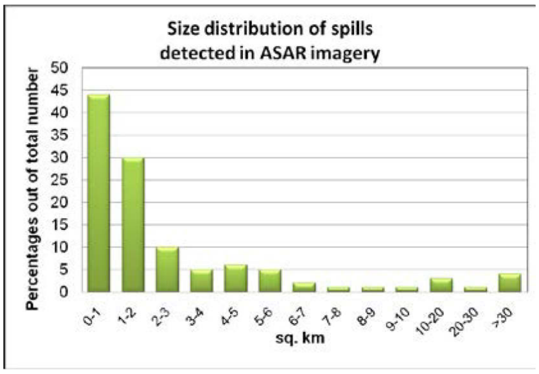

Figure 14. Size distribution of oil spills detected in the southeastern Baltic Sea

6. Conclusions

The results of the operational monitoring performed in June 2004 – November 2005 (see a map in Fig. 15) were compared with the up-to-date situation (2009-2011). It can be concluded that the situation with the anthropogenic oil pollution in Baltic Sea have much improved last years. This fact is supported by other sources and data on oil pollution in the Baltic Sea (Kostianoy and Lavrova, 2014a,c).

It could be a result of increased control of various national and international organizations in the Baltic Sea countries on the sea pollution. The illegal ship discharges as well as outflows of local rivers and Pilava Strait continue to be the main sources of the oil pollution. The ship discharges traditionally take place at an anchorage site near the entrance to the Pilava Strait (Kaliningrad Canal), along the main navigation route eastward of the Gotland Island, along the shipping routes to the Klaipeda and Liepaja ports, and in the Hel Spit area.

Satellite radar imagery provides effective capabilities to monitor oil spills, in particular, in the Baltic Sea. Combined with satellite remote sensing of SST, sea level, chlorophyll concentration, mesoscale dynamics, wind and waves this observational system represents a powerful method for a long-term operational monitoring of ecological state of semi-enclosed seas especially vulnerable to oil pollution.

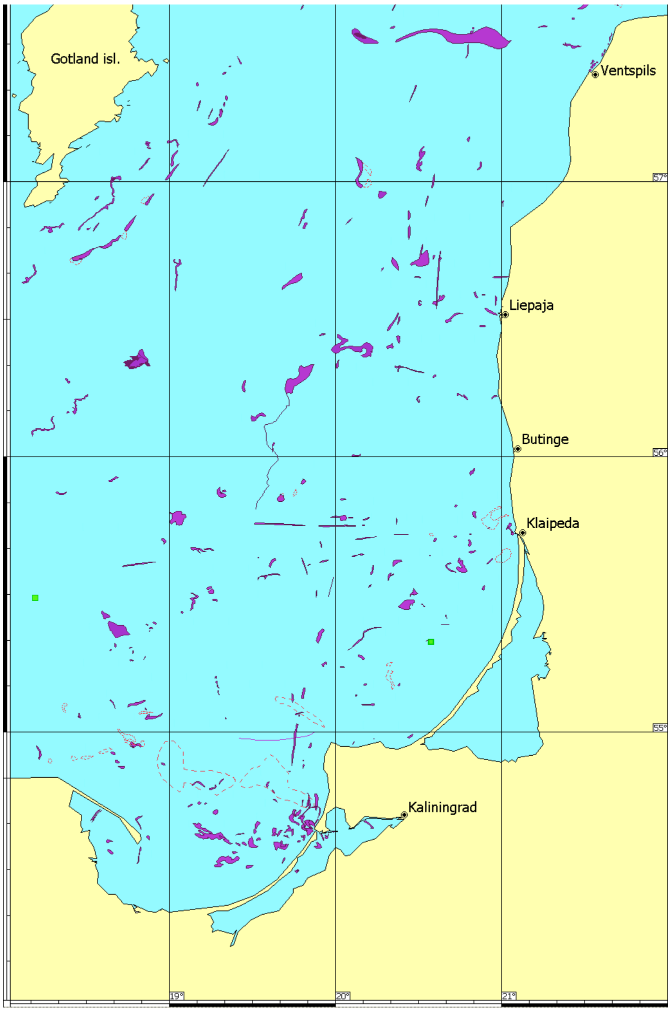

Figure 15. Map of all oil spills detected by the analysis of the ASAR ENVISAT and SAR RADARSAT imagery in June 2004 – November 2005(after Kostianoy et al., 2006)

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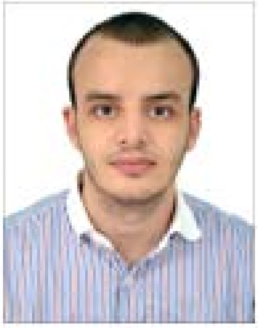

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- **Education:** Ph.D. in Artificial Intelligence program of Computer Science graduate at University of Oran in 2006, Head of Computer Science department, head of Aid and Piloting System team of LIO Laboratory in Oran1 University, in 2012 appointed as a Professor
- **Publications**: 1 monographs, 3 text books and scriptum, more than 90 scientific papers including journal articles and domestic and international conference and congress contributions and presentations
- **Field of research**: application of information technology, decision support system (urban, road and maritime transportation), optimization, cooperative and distributed system, Knowledge bases

Adam Torok

- Researcher at KTI – Institute for Transport Sciences and part time lecturer at Budapest University of Technology and Economics
- **Education:** MSc in Transport Engineer, Budapest University of Technology and Economics (1999–2004), MSc in Transport Management, Budapest University of Technology and Economics (2004–2007); PhD (Dr) in Transport Sciences, Budapest University of Technology and Economics (2008), junior researcher (2007-2008), researcher (2008-)
- **Publications**: author or co-author of 174 publications
- **Field of research:** transportation engineering, passenger cars, mathematical modelling

Dr. Árpád Török (born in Hungary)

- Deputy Head of Road Safety Centre, Institute for Transport Sciences
- **Education and Scientific activities:** Doctor of Philosophy degree (Ph.D) in transport sciences, regular member of several national and international scientific and professional organisations (EuroTra, AET, KTE, MMK, etc.). Participated in many national and international research projects (CONTRA, TRANS-AID, EuroRap, etc.) and worked as a guest researcher at several collaborating research institutes (INRETS, IVR). The speaker takes part regularly in road safety conferences, also publishing his research results.
- **Fields of research:** Transport Safe]\'ty, Transport Economics, Urban Economics, Linear Programming

Florian Heinitz (born in 1972)

- Professor at Erfurt University of Applied Sciences, Transport and Communications Department since 2004.
- **Education & Scientific and University degrees:** Master degree in Physics from University of Marburg (Dipl-Phys.), Ph.D. In economic sciences from University of Karlsruhe.
- **Scientific activities:** In 2007 has joined the IVR Transport and Spatial Planning Institute which he has been leading since 2011.
- **Publications:** more than 20 refereed articles in journals and conference proceedings
- **Fields of research:** multi-modal transport modelling and the integration of planning results in decision support systems, aviation management and economics, particularly air freight networks.

Gunnar Prause (born in Germany, 1960)

- Professor for International Business Tallinn School of Economics and Business Administration (TSEBA) Tallinn University of Technology
- **Fields of research:** International Business, Logistics, SME – Management, Regional Development
- **Organizational activities:** Board Member of the Centre for Business Research and Development at the Department of Business Administration of TSEBA; Board Member of the Institute of Cooperative Studies at Humboldt University Berlin; Board Member of Baltic China Science Park Network
- **Publications:** more than 100 scientific articles

Oleg Solovyov (born in 1966)

- Ph.D. in Engineering Science, Honored mechanician of Ukraine, Senior research fellow
- **Education & Scientific and University degrees:** In 1988 graduated from the Kharkov Higher Military Aviation Engineering School, Specialty - Mechanical Engineer, in 2003 graduated from the Kharkov branch of Ukrainian Academy of Banking, Specialty - economist
- From 2003 Director of the State enterprise "Chuguev aircraft repair plant", from 2011, the Associate Professor of the department of chemistry, ecology and examination technologies of National Aerospace University - Kharkov Aviation Institute.
- **Publications:** more than 20 scientific works, the coauthor of eight patents and one national aviation standard of Ukraine.
- Awarded with medals and honors of the Ministry of defense and other defense and security agencies of Ukraine.
- **Areas of expertise**: technological processes and equipment for installation and assembly work and emergency operations during space flights, environmental security, trailing vortices behind aircrafts.

Sergey Yeryomenko (born in 1958)

- Specialist in the field of aerodynamics of subsonic speeds. Ph.D. in Engineering Science (1996).
- **Education:** In 1978 graduated from the Kharkov Higher Military Aviation Engineering School.
- 1992–2009 lecturer at the Department of aerodynamics the Air Force Engineering Academy named by Professor N. Ye. Zhukovsky, from 2009 – Assoc. Prof. of Aerohydrodynamics of the National Aerospace University - Kharkov Aviation Institute.
- **Areas of expertise:** aerodynamics of subsonic speeds, trailing vortices behind aircrafts.

Vitaliy Kobrin (born in 1952)

- Expert in the field of aerospace engineering. Doctor of Engineering Science (1994). Professor (1998). Awards: N.E. Zhukovsky Prize (1984), A. Bereznyak Medal (2005), decoration "For scientific achievements" of Ministry of Education (2005).
- **Education:** Graduated from Kharkov Aviation Institute (National Aerospace University - Kharkov Aviation Institute now) in 1976, Specialty - aircraft manufacturing.
- From 1994 head of the Department of aircraft production, from 2001 – Dean of the Aircraft Building Faculty of the National Aerospace University - Kharkov Aviation Institute.
- **Areas of expertise:** technological processes and equipment for installation and assembly work and emergency operations during space flights (projects were used during manned flights on the orbital complex "Mir"), environmental security, trailing vortices behind aircrafts.

Vorobiev Yuriy

- Professor of the Department of aircraft production of the National Aerospace University - Kharkov Aviation Institute.
- **Education & Scientific and University degrees:** In 1986 graduated from Kharkov Aviation Institute, Ph.D. in Engineering Science, Professor.
- **Scientific activities:** More than 20 years of experience in research and development in the field of lean manufacturing, advanced assembly techniques, technology and power tools for assembly and installation of aircraft structures. Participated in the development of production technology for a number of AN, MiG and Su aircraft models and other aviation products.
- **Publications:** over 90 scientific papers: monographs, standards, scientific articles and inventions.

Larin Oleg (born in Nefteyugansk, Russia, April 2, 1972)

- Professor at Moscow State University of Railway Engineering (MIIT), The Institute of Management and Information Technology, member of APICS in the status of Academic professional
- **Education&Scientific and university degrees:** Engineer in Transport Management (1995), Lawyer (1996), Chelyabinsk State Technical University; Ph.D. in 1998, Dr.Sc. (Tech) in 2009 at Moscow State Automobile & Road Technical University - MADI
- **Publications**: 6 monographs, 23 text books and scriptum, more than 140 scientific papers including journal articles and domestic and international conference and congress contributions and presentations
- **Field of research**: modeling of traffic flows, traffic management, development of methods for predicting the state of traffic flow, supply chain management

Dosenko Victor (born in Leningrad, Russia, February 23, 1947)

- First Vice President of the International Transport Academy, Academician; full member of the International Transport Academy of CIS
- **Education&Scientific and university degrees**: 1975-1980 Leningrad Electro-technical and Communications Institute: Engineer, Electro-Technics and communications; 1980-1984 Borochevskyi Road Transport Technical Institute; Civil Engineer, Transport;
- **Publications**: He participated in the redaction and editing of the Russian version of several books in road engineering:
  Environmental impact assessment in highway construction and design (Italian and Russian versions), Pavlovsk, April, 1994
  Motorways. Swedish standards of the 90ies. Russian version, 1998
  "White paper: European Transport policy for 2010: time to decide", Moscow 2003.
  "Road to ITS" Swedish Manual, Moscow 2010
  IRF Vienna Manifesto on ITS, Moscow 2013
  ITS in road transport, Manual of Turin Polytechnic University, Moscow 2014
- more than 90 journal articles and domestic and international conference and congress contributions and presentations
- **Field of research**: ITS, traffic management, training in all aspects of transport through workshops and seminars.

Olga Lavrova

- Head of Space Radar Laboratory in the Department of Remote Sensing of the Earth at Space Research Institute of Russian Academy of Sciences since 1985.
- **Education & Scientific and University degrees:** master degree in Mechanics from the Moscow State University in 1979. In 1995 - degree of Candidate of Science from Space Research Institute of RAS.
- Co-edited a book published by Springer "Oil pollution in the Baltic Sea", also a lecturer at Moscow Technical University of Radiotechnics and Electronics.
- **Publications:** more than 70 papers in peer-reviewed journals and books, and more than 100 papers elsewhere (e.g. in conference proceedings).
- **Fields of research:** oceanography, coastal processes, and their remote sensing using synthetic aperture radar, optical and infrared sensors. Involved in the field experiments.

Marina I. Mityagina

- Senior Research Scientist in the Space Research Institute of Russian Academy of Sciences and holds a Ph. D. degree in physics and mathematics.
- **Publications**: more than 100 scientific papers and co-authored 5 books.
- **Field of research**: wide experience in the satellite remote sensing of the ocean and marine atmosphere. Current research includes analysis and interpretation of SAR signatures of ocean features associated with spatially varying surface currents and winds, oil pollution phenomena, eddy and wave processes in coastal zones, as well as investigation of meso- and submesoscale circulation and its effects on biological productivity and transport of pollutants.

Andrey G. Kostianoy

- Professor, Doctor of physico-mathematical sciences, Chief Scientist at the P.P. Shirshov Institute of Oceanology of the Russian Academy of Sciences (Moscow, Russia), a Professor at the University of Liege (Belgium).
- **Scientific activities:** Member of the Intergovernmental Panel on Climate Change (IPCC). Member of several international scientific organizations and editorial boards of international journals, Editor-in-Chief of one of the Springer's (Germany) book editions - "The Handbook of Environmental Chemistry". In 1993-2013 led 35 national and international research projects aimed to investigation of, in particular, the environment of the Black, Azov, Caspian, Aral and Baltic seas, oil pollution in the Russian seas, regional climate change of the Russian seas. Headed complex operational satellite monitoring of: (1) Kravtsovskoye oil field in the Baltic Sea (Lukoil D-6 oil platform) (2004-2005); (2) Offshore gas pipeline "Dzhubga-Lazarevskoye-Sochi" in the Black Sea (2010); (3) Offshore gas pipeline "Nord Stream" in the Gulf of Finland (2010-2013).
- **Publications:** over 500 scientific publications, including 30 books published in Springer and Russian editions, most of which is devoted to the study of the Black, Caspian, Aral and Baltic seas.
- **Fields of research:** physical oceanography, satellite remote sensing of the oceans and inland seas, regional climate change.

Aleksandr V. Semenov

- Professor, Doctor of Economics, Professor, Rector at S.Yu. Witte Moscow University (Moscow, Russia), Honorary Professor at Higher School of Finance and Management (Bialystok, Poland).
- **Publications:** more than 50 scientific publications, author and editor of 10 books, including the Encyclopedia of the Adriatic Sea, White Sea, East-Siberian Sea and Baltic Sea, published in 2014 by the publishing house "International Relations" (Moscow, Russia).

CUMULATIVE INDEX

TRANSPORT and TELECOMMUNICATION, volume 15, no. 4, 2014 (Abstracts)

Gogas, M., Papoutsis, K., Nathanail, E. Optimization of Decision-Making in Port Logistics Terminals: Using Analytic Hierarchy Process for the Case of Port of Thessaloniki, *Transport and Telecommunication*, vol. 15, no. 4, 2014, pp. 255–268.

The management models pursued in logistics terminals determine their performance to a great extent. Terminals managed by public actors usually incorporate more social criteria into their decision-making processes. In addition, private management focuses on economic viability of the initiative. Decision-making is a complex process regardless the structure of management or the decision models useddue to the fact that a wide range of diverse criteria are embedded into this process. The objective of this paper it to determine a prioritization of a set of alternative options for investment projects which were suggested by port executives taking into account criteria and evaluation that have already validated by them. In order to perform the analysis a multi-criteria decision-making model was used: the Analytic Hierachy Process. The outcomes support a low-biased and efficient strategic planning through a balanced decision-making framework.

Keywords: ports; decision-making; AHP; logistics teminals; management structures; Thessaloniki

Tettamanti, T., Horváth, M.T., Varga, I. Road Traffic Measurement and Related Data Fusion Methodology for Traffic Estimation, *Transport and Telecommunication*, vol. 15, no. 4, 2014, pp. 269–279.

The knowledge of road traffic parameters is of crucial importance to ensure state-of-the-art traffic services either in public or private transport. In our days, a plethora of road traffic data are continuously collected producing historical and real-time traffic information as well. The available information, however, arrive from inhomogeneous sensor systems. Therefore, a data fusion methodology is proposed based on Switching Kalman Filter. The concept enables efficient travel time estimation for urban road traffic network. On the other hand, the method may contribute to a better macroscopic traffic modelling.

Keywords: Road Traffic Estimation, Data fusion, Switching Kalman Filter

Bendaoud, Z., Bouamrane, K. A Traveller Information System: Minimisation of the Number of Graphs' Nodes Involved when Processing Route Requests, *Transport and Telecommunication*, vol. 15, no. 4, 2014, pp. 280–291.

The number of people using public transport is continuously increasing. Transport companies want to fulfil travellers' expectations wherever possible. However, the great number of public transport companies operating in the same area can sometimes confuse travellers as to which route they should take and how to obtain the information relative to their journey. In this paper we suggest integrating several traveller information systems from different companies into the same multimodal information system, offering companies the choice not to share their data. This encourages them to join the system. Additionally, we have minimised the number of nodes involved when processing travellers' requests in order to simplify the calculation process. To put our plan into action, we have opted for a multi-agent system coupled with the Voronoi decomposition for managing the network.

Keywords: Information system, traveller information, multi-agent systems, Voronoi decomposition

Torok, Ad., Torok Ar., Heinitz, F. Usage of Production Functions in the Comparative Analysis Of Transport Related Fuel Consumption, *Transport and Telecommunication*, vol. 15, no. 4, 2014, pp. 292–298.

This contribution aims to examine the relationship between the transport sector and the macroeconomy, particularly in fossil energy use, capital and labour relations. The authors have investigated the transport related fossil fuel consumption 2003 - 2010 in a macroeconomic context in Hungary and Germany. The Cobb-Douglas type of production function could be justified empirically, while originating from the general CES (Constant Elasticity of Substitution) production function. Furthermore, as a policy implication, the results suggest that a solution for the for the reduction of anthropogenic CO2 driven by the combustion of fossil fuels presupposes technological innovation to reach emission reduction targets. Other measures, such as increasing the fossil fuel price by levying taxes, would consequently lead to an undesirable GDP decline.

Keywords: production function, environmental pollution, transport emission, fossil fuels

Prause, G. A Green Corridor Balanced Scorecard, *Transport and Telecommunication*, vol. 15, no. 4, 2014, pp. 299–307.

Green transport corridors represent trans-shipment routes with a concentration of freight traffic between major hubs and long distances of transport marked by reduced environmental and climate impact. Important characteristics of green corridors are their network structures, their transnational character and their high involvement of public and private stakeholders, including political level requiring new governance models. Network-oriented controlling of green transport corridors require new concepts and instruments concentrating on multi-dimensional evaluation of collective strategies and processes in an international environment with a focus on cross-company aspects.

Until now the scientific discussion focusses on different sets of Key Performance Indicators (KPI) for monitoring and management of green corridors, which mainly cover sustainable aspects of green corridor development by neglecting a network-oriented controlling approach so that a general concept for green corridor controlling is still missing. The current KPI approaches emphasize the operational aspects of the corridor performance so that a strategic management control system is needed to safeguard an efficient, innovative, safe and environmental friendly long-term development.

The paper will present and discuss a management control system for green supply chains based on the balanced scorecard concept and link the ongoing scientific discussion to recent research results about green corridor management. The presented green corridor balanced scorecard tries to solve the strategic weakness of the existing green corridor controlling approaches by integrating cooperative and network-oriented concepts from supply chain management.

Keywords: Green Transport Corridors, Management Control Systems, Networks, Balanced Scorecard, Key Performance Indicators

Solovyov, O., Yeryomenko, S., Kobrin, V., Vorobyov, Y. Dipole Approximation in the Calculation of the Perturbed Velocities, *Transport and Telecommunication*, vol. 15, no. 4, 2014, pp. 308–314.

In this article we consider one of the approaches aimed at reducing time of calculation of aerodynamic characteristics of the studied objects using discrete vortex method. Also, accuracy assessment of calculation of aerodynamic characteristics was performed.

Analysis of the obtained dependences allows us to make a conclusion that the considered approach to the calculation of the functions of the mutual influence on the stages of formation of the system of linear algebraic equations, position of vortex sheet nodes as well as aerodynamic loads reduces hardware costs about three times, with a relative error of less than 4%.

Keywords: discrete vortex method, dipole approximation

Larin, O.N., Dosenko, V.A. Use of a Phase Transition Concept for Traffic Flow Condition Estimation, *Transport and Telecommunication*, vol. 15, no. 4, 2014, pp. 315–321.

The article covers the main models of traffic flow conditions, analyzes the condition estimation criteria, and provides the classification of models. The article provides the grounds for the use of the phase transition concept for traffic flow condition estimation. The models of the aggregate condition of free and congested traffic have been developed, the phase boundaries between free and congested traffic have been defined. Applicability conditions for the models of the aggregate condition of have been analyzed.

Keywords: traffic flow, classification condition, phase transitions

Lavrova, O.Yu., Mityagina, M.I., Kostianoy, A.G., Semenov, A.V. Oil Pollution in the Southeastern Baltic Sea in 2009-2011. *Transport and Telecommunication*, vol. 15, no. 4, 2014, pp. 322–331.

From January 2009 to April 2012 a satellite survey of the central and southeastern parts of the Baltic Sea was carried out by the Space Radar Laboratory at the Space Research Institute of Russian Academy of Sciences (RAS). The main attention was focused on the detection of oil pollution as well as biogenic and anthropogenic surfactant films. The basic data are high resolution radar images obtained by advanced synthetic aperture radar (ASAR) on board of the Envisat satellite of the European Space Agency. Remotely sensed data in visual and infrared (IR) bands acquired by sensors MERIS Envisat, MODIS-Terra and –Aqua, and AVHRR NOAA nearly simultaneously with the ASAR images, were processed and analysed in order to facilitate the discrimination between different types of surface pollutants, to understand a comprehensive features of meteorological and hydrodynamic processes in the sea area of investigation, and to reveal factors determining pollutants spread and drift. The regions of the most intense oil pollution are outlined.

Keywords: Southeastern Baltic Sea, oil pollution, satellite monitoring, synthetic aperture radar, Envisat, MODIS-Terra and Aqua

TRANSPORT and TELECOMMUNICATION, 15. sējums, Nr. 4, 2014 (Anotācijas)

Gogas, M., Papoutsis, K., Nathanail, E. Lēmumu pieņemšanas optimizācija ostu loģistikas terminālos: analītiskās hierarhijas procesa izmantošana Saloniki ostas gadījumā, *Transport and Telecommunication*, 15. sējums, Nr. 4., 2014., 255. – 268. lpp.

Vadības sistēmu modeļi, kuri tiek izmantoti loģistikas terminālos, lielā mērā nosaka to darba rezultātus. Lēmumu pieņemšanas procesi terminālos, kurus vada publiskas institūcijas, parasti ietver sevī vairāk sociālu kritēriju. Bez tam, privātais menedžments vairāk koncentrējas uz jaunu iniciatīvu ekonomisko dzīvotspēju. Tomēr, neatkarīgi no vadības sistēmas struktūras vai izmantotajiem lēmumu pieņemšanas modeļiem, lēmumu pieņemšana ir komplekss process, jo tajā tiek izmantoti daudz dažādi kritēriji. Šī raksta mērķis ir noteikt prioretizācijas veidu dažādiem investīciju projektu alternatīviem variantiem, kurus ir ierosinājusi ostas administrācija, ņemot vērā savus jau apstiprinātos kritērijus un novērtēšanas metodes. Analīzes veikšanai ir izmantots daudzkritēriju lēmumu pieņemšanas modelis - analītiskās hierarhijas process. Darba rezultāti par labāko atzīst efektīvu stratēģisko plānošanu ar zemu subjektīvo lēmumu pieņemšanas pakāpi, kas tiek realizēta sabalansētas lēmumu pieņemšanas sistēmas ietvaros.

Atslēgvārdi: ostas, lēmumu pieņemšana, analītiskās hierarhijas process, loģistikas termināls, vadības sistēmas, Saloniki

Tettamanti, T., Horváth, M.T., Varga, I. Ceļu satiksmes mērīšanas un saistīto datu sapludināšanas metodoloģija satiksmes novērtēšanā, *Transport and Telecommunication*, 15. sējums, Nr. 4., 2014., 269. – 279. lpp.

Zināšanas par ceļu satiksmes parametriem ir vitāli svarīgas, lai varētu nodrošināt mūsdienīgus satiksmes pakalpojumus gan sabiedriskā, gan privātā transporta jomās. Mūsdienās pastāvīgi tiek savākts liels daudzums datu par ceļu satiksmi, veidojot jau notikušas un reālā laika satiksmes informācijas masīvus. Vienlaikus, pieejamā informācija tiek ģenerēta dažādās nehomogēnās sensoru sistēmās. Tādēļ tiek piedāvāta datu sapludināšanas metodoloģija, kura balstās uz Kalmana filtru (Switching Kalman Filter). Šis koncepts dod iespēju veikt efektīvu brauciena laika novērtēšanu pilsētas ceļu satiksmes sistēmai. No otras puses, šī metode var palīdzēt arī labākai satiksmes makroskopiskai modelēšanai.

Atslēgvārdi: ceļu satiksmes novērtēšana, datu sapludināšana, Kalmana filtrs

Bendaoud, Z., Bouamrane, K. Ceļojumu informācijas sistēma: grafiku mezglu skaita minimizācija apstrādājot satiksmes maršrutu pieprasījumus, *Transport and Telecommunication*, 15. sējums, Nr. 4., 2014., 280. – 291. lpp.

Cilvēku skaits, kuri izmanto sabiedrisko transportu, pastāvīgi palielinās. Transporta kompānijas grib apmierināt ceļotāju cerības kur vien tas ir iespējams. Tai pat laikā, lielam skaitam sabiedriskā transporta kompāniju darbojoties vienā un tajā pašā teritorijā var rasties situācija, kad ceļotāji nonāk apjukumā nezinot, kuru maršrutu izvēlēties, un kā iegūt informāciju attiecībā uz savu ceļojumu. Šajā rakstā tiek ierosināts savstarpēji integrēt vairāku kompāniju dažādas ceļojumu informācijas sistēmas vienā multimodālā informācijas sistēmā, tai pat laikā piedāvājot kompānijām iespēju neatklāt citiem savus datus. Tas viņas iedrošina pievienoties šai sistēmai. Papildus tam ir minimizēts mezglu skaits, kuros tiek apstrādāti ceļotāju pieprasījumi, lai vienkāršotu kalkulācijas procesu. Lai ieviestu šo plānu darbībā, un, lai varētu veikt tīkla vadību, ir izvēlēta daudzaģentu sistēma, kura ir saistīta ar Voronoi sadalīšanos.

Atslēgvārdi: informācijas sistēma, ceļojumu informācija, daudzaģentu sistēma, Voronoi sadalīšanās

Torok, A., Torok, A., Heinitz, F. Ražošanas funkciju izmantošana ar transportu saistīta degvielas patēriņa salīdzinošajā analīzē, *Transport and Telecommunication*, 15. sējums, Nr. 4., 2014., 292. – 298. lpp.

Šī darba mērķis ir izvērtēt transporta sektora un makroekonomikas savstarpējās attiecības, īpaši tādās jomās, kā fosilās enerģijas izmantošana, kapitāla un darba attiecības. Autori makroekonomiskā kontekstā ir izpētījuši ar transportu saistītas fosilās enerģijas patēriņu 2003. – 2010. gadā Ungārijā un Vācijā. Cobb – Douglas tipa ražošanas funkcija var tikt apstiprināta empīriski, tiktāl, cik tā veidojas no kopējās Aizvietošanas pastāvīgās elastības (Constant Elasticity of Substitution - CES) ražošanas funkcijas. Turklāt pētījumu rezultāti, kā šādas politikas ietekmes sekas iesaka, ka nepieciešamais risinājums, lai panāktu antropogēno CO2 izmešu samazināšanos, kuri rodas sadegot fosilajai degvielai, ir tehnoloģiskas inovācijas, kas ļaus sasniegt emisijas samazināšanas mērķus. Citi iespējamie pasākumi, kā piemēram fosilās degvielas cenas celšana, ieviešot speciālas nodevas, var novest pie valsts IKP nevēlamas samazināšanās.

Atslēgvārdi: ražošanas funkcija, vides piesārņošana, transporta izmeši, fosilā degviela

Prause, G. Zaļā koridora sabalansēta rādītāju karte, *Transport and Telecommunication*, 15. sējums, Nr. 4., 2014., 299. – 307. lpp.

Zaļos transporta koridorus var raksturot kā satiksmes veidu, kur kravu pārvadāšana ir organizēta starp galvenajiem pārkraušanas centriem un tā notiek garās distancēs, kā rezultātā samazinās negatīva ietekme uz vidi un klimatu. Zaļo koridoru būtiskas iezīmes ir to tīkla struktūra, pārnacionālais raksturs un procesa publisko un privāto dalībnieku augstā iesaistes pakāpe, ieskaitot politiskā līmeņa dalībniekus, kas savukārt prasa jaunu pārvaldības modeļu izmantošanu. Zaļo transporta koridoru tīklveida kontrole prasa jaunu pieeju un līdzekļu izmantošanu, kuri koncentrējas uz kolektīvo stratēģiju un procesu daudzdimensionālu izvērtēšanu starptautiskā vidē, par mērķi izvirzot starp-kompāniju sadarbības jautājumus.

Līdz šim zinātniskā diskusija pamatā fokusējas uz jautājumu par to vai citu galveno darbības rādītāju (Key Performance Indicators – KPI) komplektu izmantošanu, lai veiktu zaļo koridoru monitoringu un vadību. Tie galvenokārt ietver zaļo koridoru ilgtspējīgas attīstības aspektus, pametot novārtā koridoru tīklveida kontroles jautājumus, līdz ar to joprojām trūkst kopējas pieejas zaļo koridoru kontroles jautājumam. Patreizējās KPI pieejas liek uzsvaru uz koridoru funkcionēšanas operacionālajiem aspektiem, kā rezultātā pastāv nepieciešamība pēc stratēģiskās vadības kontroles sistēmas, lai nodrošinātu efektīvu, inovatīvu, drošu un videi draudzīgu ilgtermiņa attīstību.

Šis raksts piedāvā un analizē zaļo apgādes koridoru vadības kontroles sistēmu, kura balstās uz sabalansētas rādītāju kartes pieeju, un sasaista pašreiz notiekošās zinātniskās diskusijas ar jaunākajiem zaļo koridoru vadības pētījumu rezultātiem. Prezentētā zaļo koridoru sabalansētas rādītāju kartes pieeja cenšas atrisināt pašreiz lietotās zaļo koridoru kontroles sistēmas vājās vietas, integrējot sevī sadarbības un tīklveida attīstības elementus no piegādes tīklu vadības sistēmas.

Atslēgvārdi: zaļie transporta koridori, vadības kontroles sistēma, tīkli, sabalansēta rādītāju karte, galvenie darbības rādītāji

Solovyov, O., Yeryomenko, S., Kobrin, V., Vorobyov, Y. Dipols tuvinājums aprēķinot perturbētus ātrumus, *Transport and Telecommunication*, 15. sējums, Nr. 4., 2014., 308. – 314. lpp.

Šajā rakstā tiek apskatīta diskrētā virpuļa metode kā viena no iespējamām pieejām, lai samazinātu laiku, kurš nepieciešams aprēķinot pētāmo objektu aerodinamiskos parametrus. Tāpat ir analizēts arī aerodinamisko rādītāju precizitātes novērtējums.

Iegūto atkarību izpēte ļauj izdarīt secinājumu, ka apskatītā savstarpējās ietekmes funkciju aprēķināšanas metode lineāru algebrisko vienādojumu sistēmas veidošanas, virpuļa mezglu pozicionēšanas un aerodinamiskās noslogošanas laikā ļauj samazināt iekārtu izmaksas apmēram trīs reizes. Relatīvā kļūda tai pat laikā ir mazāka par 4%.

Atslēgvārdi: diskrētā virpuļa metode, dipols tuvinājums

Larin O.N., Dosenko V. A. Fāžu pārejas koncepcijas izmantošana transporta plūsmu apstākļu novērtēšanai, *Transport and Telecommunication*, 15. sējums, Nr. 4., 2014., 315. – 321. lpp.

Šis raksts apskata transporta plūsmu apstākļu galvenos modeļus, analizē apstākļu novērtēšanas kritērijus un piedāvā modeļu klasifikāciju. Raksts piedāvā izmantot fāžu pārejas koncepciju transporta plūsmu apstākļu novērtēšanai. Ir tikuši izveidoti kopējā stāvokļa modeļi brīvas un pārslogotas satiksmes apstākļiem, nosakot arī fāžu robežas starp brīvu un pārslogotu satiksmi. Tāpat ir pētīti pārslogotas satiksmes analīzes modeļu piemērojamības nosacījumi.

Atslēgvārdi: transporta plūsma, klasifikācijas nosacījumi, fāžu pāreja

Lavrova, O., Mityagina, M., Kostianoy, A., Semenov, A. Naftas piesārņojums dienvidaustrumu Baltijas jūrā 2009.-2011. *Transport and Telecommunication*, 15. sējums, Nr. 4., 2014., 322.–331. lpp.

No 2009.g. janvāra līdz 2012.g. aprīlim Krievijas Zinātņu akadēmijas Kosmosa Pētniecības Institūta Kosmosa radaru laboratorija veica pavadoņa pētījumu par Baltijas jūras centrālajiem un dienvidaustrumu reģioniem. Uzmanība tika pievērsta tieši naftas piesārņojuma konstatēšanai. Pamatdati ir iegūti no augstās izšķirtspējas radara attēliem, kas iegūti no radara ar uzlaboto sintētisko diafragmu no Eiropas Kosmosa Aģentūras Envisat pavadoņa.

No attāluma uztverami dati vizuālajās un infrasarkanajās joslās tika iegūti no sensoriem MERIS Envisat, MODIS-Terra un Aqua, un AVHRR NOAA gandrīz vienlaicīgi ar ASAR attēliem tika apstrādāti un analizēti, lai varētu atvieglot diskrimināciju starp dažādiem virsmas piesārņojošiem veidiem, kā arī, lai saprastu meteoroloģisku un hidrodinamisku procesu vispusīgas īpatnības jūras pētījuma zonā, un lai atklātu faktorus, kas nosaka piesārņojuma izplatīšanos un virziena maiņu.

Ir atzīmēti reģioni, kas ir pakļauti vislielākajam naftas piesārņojumam.

Atslēgvārdi: dienvidaustrumu Baltijas jūra, naftas piesārņojums, sintētisko diafragmu radar, Envisat, MODIS-Terra un Aqua

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$$\sqrt{a^2 + b^2} \tag{1}$$

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Text	Text	Text

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Example: Kayston, M. and Fried, W. R. (1969) *Avionic Navigation Systems.* New York: John Wiley and Sons Inc.

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2. Conclusions

Conclusion section (this is mandatory) – should clearly indicate on the advantages, limitations and possible applications.

Acknowledgements (‘T&T_Heading_nonum’ style)

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Acknowledgements (if present) mention some specialists, grants and foundations connected with the presented paper.

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1. Gibson, E.J. (1977) The performance concept in building. In: *Proceedings of the 7th CIB Triennial Congress*, Edinburgh, September 1977. London: Construction Research International, pp. 129–136.
2. Kayston, M. and Fried, W. R. (1969) *Avionic Navigation Systems.* New York: John Wiley and Sons Inc.
3. Ministerial Council on Drug Strategy. (1997) *The national drug strategy: Mapping the future*. Canberra: Australian Government Publishing Service.
4. Nikora, V. (2006) Hydrodynamics of aquatic ecosystems. *Acta Geophysica,* 55(1), 3–10. DOI:10.2478/s11600-006-0043-6.
5. Osgood, D. W., and Wilson, J. K. (1990) *Covariation of adolescent health problems*. Lincoln: University of Nebraska. (NTIS No. PB 91-154 377/AS).

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