ISSN 1407-6160

TRANSPORT AND TELECOMMUNICATION

Volume 10. No 2

2009

Transporta un sakaru institūts
(Transport and Telecommunication Institute)

Transport and Telecommunication

Volume 10, No 2 - 2009

ISSN 1407-6160
ISSN 1407-6179
(On-line: www.tsi.lv)

Riga – 2009

05/J80

Host Organizations:
Transport and Telecommunication Institute, Latvia – Eugene Kopytov, Rector
Telematics and Logistics Institute, Latvia – Igor Kabashkin, Director

Supporting Organizations:
Latvian Transport Development and Education Association
Latvian Academy of Sciences
Latvian Operations Research Society
Telecommunication Association of Latvia
Latvian Academic Park

All articles are reviewed.
Articles can be presented in the journal in English.

EDITORIAL CORRESPONDENCE

Transporta un sakaru institūts (Transport and Telecommunication Institute)
Lomonosova iela 1, LV-1019, Riga, Latvia. Phone: (+371)67100594. Fax: (+371)67100535.
E-mail: kiv@tsi.lv, http:// www.tsi.lv

TRANSPORT and TELECOMMUNICATION, 2009, Vol. 10, No 2
ISSN 1407-6160
The journal of Transport and Telecommunication Institute (Riga, Latvia).
The journal is being published since 2000.

The papers published in Journal "Transport and Telecommunication" are included in
SCOPUS (since 2008, Vol. 9, No 1), **Elsevier Database**
www.info.scopus.com
www.elsevier.com

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Transport and Telecommunication Institute, Lomonosova 1, Riga, LV-1019, Latvia

ESTIMATION OF LOGISTICS SITUATION CHANGES 2007-2009 IN LITHUANIA

***Darius Bazaras*[1], *Ramūnas Palšaitis*[2]**

Vilnius Gediminas Technical University
Plytines Str. 27, Vilnius, LT-10105, Lithuania
E-mails: [1]dbazaras@vv.vgtu.lt; [2]trvadyba@ti.vgtu.lt

Surveys of logistics situation in Lithuania have been performed in Vilnius Gediminas Technical University in 2007. This survey discovered mostly relevant problems in logistics: costs policy, logistics competences, and personnel competence development requirements. During this investigation the positive trends of logistics IT systems development have been identified. The product customisation, inventory management, warehousing, invoicing, order processing and reverse logistics outsourcing are relevant. The majority of Logistics companies supposed that their operating environment in Lithuania is good enough. Surveys results indicate that Lithuanian logistics companies have positive tendencies in the self assessment from the different point of view. In this article the main results of this survey are presented. In light of economical crisis of the end of 2008 the main survey results are revised and new surveys' directions for future investigations are formed.

Keywords: logistics, transport policy, survey

1. Introduction

During last years Lithuania has been named as logistics country and it is true because since the first years of Lithuania's independence, the image of the country is being established as "a transit and logistic service country", which through its international transport corridors connects West and East, as well as South and North European countries. In 2007 Vilnius Gediminas Technical University participated in the international project "LogOn Baltic" and performed wide logistics situation survey. In general surveys' results have showed that logistics situation in Lithuania is enough positive and has good tendencies of the growing. Also the survey uncovers the situation with logistics and information-communication technologies situation in Lithuania not so optimistically because level of the implementation of the new modern technologies in business is not high enough. The development of personnel competence in the different business groups is insufficient: personnel need basic logistics skills and basic concepts linked to supply chain management. But at this moment – after two years – it is very important to revise results and evaluate them from the new point of view because situation in the market and general economical situation is changing very quickly and dramatically.

2. Methodology of the Survey

Three versions of surveys diverted to three types of companies have been used: manufacturing/construction companies, trading companies, logistics service providers. The questionnaires consisted of two parts: one part with general questions (being the same for the three types of companies), and another part with specific questions concerning the type of companies mentioned above. The same questionnaire has been used in all regions. Each region had the opportunity to add one or two questions focusing on specific regional issues. The regional reports therefore were slightly different. The survey was mainly conducted as a web-based survey, but mail surveys, phone surveys and interviews had also been used as a complement in some regions. The survey was performed in 2007.

In total 108 companies participated in the logistics survey. By companies size distribution range we can predicate that the biggest part is micro-sized companies – 49 % and small-sized companies – 30 %, other are the following: medium-sized – 17.5 % and large-sized – 3.5 %. In the survey 22 % (24) of the respondents represented manufacturing, 33 % (35) trade and commerce and 45 % (49) logistics companies. Favourable opportunities emerge for Lithuania to utilize its geographic position on the Eastern borders of the EU. Another key event was Lithuania entering into EU, which made cargo transportation within the EU easier, more predictable and precise, although somewhat complicating were the connections with the countries outside the EU.

The different rage of the companies' staff takes part in this survey. The survey is carried out among various categories of personnel, but the majority of people interrogated consists of senior management 33 % (36), middle management 33 % (36), operational staff 21 % (23), experts 1 % (1). The more or less equal coverage of various categories of personnel makes this survey quite of a high quality and reliable. This coverage influences the competence of answers because the biggest part of respondents are senior and middle level managers (in total 66 %) who have enough experience and information from different company's activity fields.

The main themes of the survey are as follows:

- Current logistics costs and their development;
- Key logistics indicators, including lead time, and customer service;
- The need for further competence development;
- Outsourcing, the situation today and expected development within the firm;
- Operating environment, an assessment of the regional pros and cons;
- Self assessment of the company's logistics activities and future development directions.

In this article authors will concentrate attention on logistics service providers investigation results because it relates with the main problematical point and assumption that logistics service providers are most sensitive in crisis case.

3. Main Findings from Logistics Service Providers

Survey results allow predicating that logistics companies provide evolution in standardized service packages; it will increase from 10 % to 20 %. Warehousing services will be in the same positions, but transportation amount will decrease from 60 % to 47 %. Companies are planning that Customized service package will reduce from 11 % to 8 %. Last-mentioned fact is not so good but we can analyse it from different points of view. Firstly, companies are trying to optimise their activities and use some standardization issues. Also standardization and orientation to standardized service packages are related with striving to improve quality and use some quality standards. The Lithuania companies are faced with growing personnel costs and lack of the qualified labour force it is understandable that customized services packages are not so welcome. In many cases customized services packages need additional personnel and it's difficult to standardize. It is positive that companies try to extend own services and deny simple functions as transportation only.

Analysis of relative trends of logistics service outsourcing we can predict that the greatest expectations are connected with Logistics IT systems, 3PL/4PL services, international transportation and freight forwarding. In whole all logistics activities are related with additional cost and are understandable as outsourcing (international transportation, domestic transportation, freight forwarding, order processing, invoicing, warehousing, inventory management, product customisation, 3PL/4PL service). Tendencies are positive for all logistics operations. Especially the big demand of international cargo transportation and logistics information systems development are pre-planned. From another hand – we face with some misunderstandings between logistics companies and manufacturing and trade companies because the some trends are totally different. For example, freight forwarding, international transportation and domestics' transportation have negative trends in this case. Possible business conflicts between logistics companies and their potential clients are anticipated. It is identified – the need for better cooperation between logistics companies and their clients. It can be achieved by as follows:

- improving existing contacts and cooperation process;
- improving preparation for possible cooperation process: market analysis, clients needs analysis, orientation to individual clients needs.

Logistics companies emphasize that the mostly important personnel competence needs are related with as follows:

- transportation management,
- management of innovations,
- supply chain management.

It is understandable because transportation costs are rising and the better service results can be achieved by implementing new energy-saving technologies and methods. At the same time the logistics companies' profitability is connected with better management and organization structure.

Innovation and management changes demands are correlating with situation in the market.

During the performed analysis the kind of a threat to the largest logistics service companies has been noted:

- tightening competition;
- increasing cost of services;
- decreasing demand of logistics services;

- deficiency of competent staff.

All these threats are connected with companies' business organization processes, quality of the services, costs and market demands. It is very important, that companies understand these threats and look for the possibilities to reduce them. The most important future development is connected with the following:

- extending range of offering services;
- improvement of customers service quality;
- cutting service costs;
- the personnel training and competence development.

The majority of logistics companies suppose that their operating environment in Lithuania is good enough. Concerning the opinion to the transport infrastructure about 40 % of respondents can agree that it is quite good quality, but nearly 10 % of respondents assume that transport infrastructure is insufficiently good.

It can be explained that logistics services providers are on the development process and they don't have clear opinion about market conditions. From one point of view it is dangerous because this sector becomes sensitive but from another point of view – it is an open question for future development and looking for better positions in the market.

Survey results identify not well enough situation in the IT sector because companies are too much using traditional ICT facilities: 70 % are using traditional mail/telephone/fax; over 77 % using e-mail. Usage of modern ICT is very low: RFID – 0 %, barcodes – 7 %, intranet/extranet portals – 10 %, Web-based portal – 20 %. It shows not only low ICT usage but time and efficiency losses in clients' services.

4. Self Assessment of the Companies

Results of the self assessments of the logistics companies are presented in Tables 1-4. According to survey results we can predicate that Lithuania logistics companies have positive tendencies in the self assessment from the different points of view. It was quite unexpected – 72 % of companies noticed that their firm was able to meet the quoted or anticipated delivery dates and quantities on a consistent basis. Especially over 70 % of the firms are able to respond to the demands of key customers.

Table 1. Companies' self assessment on complexity in the supply chains

	Much worse	Worse	Neither worse nor better	Better	Much better
My firm has been able to reduce the time between order receipt and customer delivery to as close as zero as	0	2	15	15	11
My firm is able to meet the quoted or anticipated delivery dates and quantities on a consistent basis	0	1	11	19	13
My firm is able to respond to the needs and wants of key customers	0	2	11	19	11
My firm is abel to notify customers in advance of delivery delays and product shortages	0	2	10	17	14
My firm is able to modify order size, volume or composition during logistics operations	1	0	14	14	8
My firm is able to accommodate delivery times for specific customers	0	1	5	17	17

In self assessment on the future of supply chain are dominated positive estimations also. More than 82 % of companies notice that they regularly monitor and evaluate their logistics costs and performance internally. 87 % of the companies notice that they regularly monitor and evaluate logistics costs and performance with selected suppliers and/or customers.

Table 2. Companies' self assessment on the future development of supply chains

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
We regularly monitor and evaluate our logistics costs and performance internally	0	0	7	18	15
We regularly monitor and evaluate logistics costs and performance with selected suppliers	0	0	5	24	9
We regularly benchmark logistics performance metrics against our competitors	0	4	12	19	4
Regular monitoring and evaluaton of logistics benefits our firm	0	3	6	23	9
We regularly monitor the environmental effects of our logistics operations	0	3	12	16	4

94 % of the companies identify that they agree or strongly agree with proposition that they effectively share operational information within the firm and internal collaboration of logistics operations is quite good. 63 % of the companies agree that their own information systems provide operational managers with sufficient and timely information to manage logistics activities.

Table 3. Companies' self assessment on internal collaboration in logistics operations

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
We effectively share operational information within our firm	1	1	1	28	15
We are well prepared for internal disturbances and irregularities in our operations	0	4	14	21	2
Our information systems provide operational managers with sufficient and timely information to manage logistics	1	6	5	26	3
Strategic planning and target setting is done in collaboration between functions/ departments	0	3	8	25	5

Some problematical points – it has been identified on external collaboration of logistics operations: 29 % of the companies disagree and 24 % of the companies do not have clear position about their information systems exchange operational information with selected subcontractors and/or customers.

Table 4. Companies' self assessment on external collaboration in logistics operations

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
We effectively share operational information with selected suppliers and/or customers	1	3	17	20	3
We are well prepared for external disturbances and irregularities in our operations	0	8	14	18	3
Our information systems support the sharing of operational information with selected suppliers and/or	0	12	10	17	3
We effectively collaborate with selectd suppliers and/or customers to facilitate operational planning and to improve	1	7	10	20	3

5. Reviser's Point of View to Situation Changes

Contemporary Lithuania's logistics business system sustained very heavy losses from nowadays economical crisis which has started in the second half of 2008. Probably that the researcher still has not reliability data about crisis influence to logistics business and market situation in general, because time period for surveys is too short. Totally by the survey results of year 2007 – it is possible to make the assumptions for estimation of the situation.

Firstly, the crisis impact for logistics business in Lithuania was very sudden but still expected – some logistics companies expected negative changes in the market. Managers of logistics companies noticed that logistics business growth was very intensive and related with tricky logistics projects. For instant according to statistics Lithuania Gross Domestic Product (GDP) in 2006 against 2005 grew by 7.7 %. In the economic activity of transport and warehousing the GDP at current prices in 2006 accounted for LTL 7.3 billion, while in that of post and telecommunications – LTL 2.1 billion. In 2006 a relative share of transportation and warehousing amounted to 9.9 % of GDP, while that of post and communications – 2.9 %. In 2006 the GDP in transport and warehousing increased by 12.2 % while in post and communications against 2005 – 6.2 %. Plausible these figures were the indicators of the "gold age" in Lithuania logistics development and it would not be in the nearest future.

In the first stages of economical crisis the total consumption starts sinking down and it makes an influence to logistics companies directly – a number of orders start to diminish. This situation makes an influence to competition in the logistics market. In 2007 the largest threats to logistics services were tightening competition and decreasing in the demand of logistics services. It shows that companies' "feeling of the situation" is correct.

Another new actual point for analysis is the personnel. In 2007 Lithuania logistics companies have faced with growing personnel costs and lack of the qualified man power but now – situation have changed crucially. The second crisis results after slow down consumption is unemployment. Joblessness is changing the needs for personnel and point of view to workplace maintaining. We can expect that personnel cost will decrease and companies will have possibilities to select competent employees from overfull labour market. Plausible that logistics companies will change personnel training policy – they will try to find qualified employees and save money for training.

In general crisis will have serious influence to logistics market in Lithuania because the main conclusion in 2007 survey is that survey passed permissions that trade companies are acting in the enough stressful market conditions; the manufacturing companies has found own place in the market; logistics companies are on the own market formation process. From one hand crisis will change balance of the logistics' market participants dramatically – weak companies will be bankrupt and companies with qualified personnel will survive. From the other hand – for new logistics companies after crisis will emerge free space in the market. In general we can predict that crisis will create clearer and stronger logistics market in Lithuania.

As it was mentioned above – that these points of view to changes in logistics market in Lithuania are theoretical only. But it is good basement for revision of the previous surveys results and creation more detailed and clear model of the logistics situation and its transformation.

6. Summary and Conclusions

1. The survey has been carried out among various categories of personnel, but the majority of people interrogated consist of senior management 33 %, middle management 33 %, and operational staff 21 %, expert 1 %. The more or less equal coverage of various categories of personnel makes this survey of the enough quality and reliable.

2. It is possible to predicate that the biggest part of logistics costs are related with transportation and inventory carrying costs. It depends on the rising prices of the energy recourses and growing consumption. This premise can be right because manufacturing companies identified that the biggest growth will be in transportation costs – over 60 %, inventory carrying costs – over 50 % and logistics administration costs – over 50 %.

3. Analyses show that manufacturing companies mostly need develop personnel's competence of basic logistics skills, basic concepts linked supply chain management and supply chain strategy. It could be explained as fundamental demand to better understanding of business processes and business globalisation tendencies.

4. Analyses of development needs of the personnel competence in the trade companies are more or less similar with the manufacturing companies. Requirements for supply chain management and basic logistics are dominating in the list of needs.

5. The positive trends of logistics IT systems, product customisation, inventory management, warehousing, invoicing, order processing and reverse logistics outsourcing are relevant.

6. Survey results show and confirm prediction that Lithuanian manufacturing companies are more optimistic in comparison with trade companies. 79 % of the manufacturing companies estimated the general business perspectives as good.

7. The trade companies' opinions on their operating environment are the same but this group of the companies identified more problems in the transport infrastructure: ~7 % of the trading companies estimated situation as poor, and the same percent estimated general business perspectives as poor.

8. Modern ICT are used insufficiently. We can not declare that modern technologies, except mail/phone/fax and e-mail, are unused but level of the using modern IT technologies is still low.

9. Over 60 % of companies understand positive side of monitoring of the impact of supply chain management on the results of their logistics activities. It has been identified that Lithuania companies are not sure that they can make correct solutions and are prepared for external disturbances. Approximately 45 % of the companies declared that they are not prepared for external disturbances and irregularities in their operations.

10. According to survey results we can predicate that logistics companies provide evolution in standardized service packages, it will increase from 10 % to 20 %. Warehousing services will be in the same position, but transportation will reduce from 60 % to 47 %. Also companies provide that customized service package will reduce from 11 % to 8 %.

11. Logistics companies point out that the mostly important personnel competence needs are related with transportation management, innovations and management changes and business strategy.

12. Crisis will have serious influence on logistics market in Lithuania. Trade companies are acting in the stressful enough market conditions; the manufacturing companies have found their own place in the market; logistics companies are on the own market formation process.

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Transport and Telecommunication, 2009, Volume 10, No 2, 10–15
Transport and Telecommunication Institute, Lomonosova 1, Riga, LV-1019, Latvia

COMMON VIRTUAL ENVIRONMENT IN THE EUROPEAN TRANSPORT TRAINING

Igor Kabashkin[1], Hans-Jörg Lotter[2]

[1]President of Transport and Telecommunication Institute
Lomonosova Str.1, Riga, LV-1019, Latvia
Ph.: +371 67100594. Fax: +371 67100535. E-mail: kiv@tsi.lv

[2]President of Infowerk Multimedia
Martinsbühel 6, A-6170 Zirl, Austria
Ph.: +43(0)5238/52099-0, Fax: +43(0)5238/52099-4. E-mail: hansjoerg.lotter@infowerk.at

The creation of a united European transport market without restrictions or barriers to access, based on harmonised conditions of competition, is becoming one of the principal objectives of common transport policy in Europe.

In the same way as transport systems, processes and services operate in an increasingly more European framework, transport education and training need to change their contents taking international aspects and globalisation into consideration and move from conventional to networked environments. Even initial transport education processes at vocational and higher educational levels must be a part of these dynamic changes to enable their graduates to meet employers' needs and perform at the market.

The establishment of Innovative Virtual European Transport Training Agency (IVETTA) is one of the steps toward this direction.

The IVETTA is an educational network of persons and institutions involved in transport education and training and interested in supporting it by use of multimedia and information technologies. It focuses on enabling transport educators and trainers to introduce any kinds of educational multimedia, new technologies and common standards to their educational processes as knowledgeable consumers or well acquainted supervisors or even to become enthusiastic multimedia developers. For this, there is required not only an appropriate technological infrastructure but also an organizational basis and culture encouraging collaboration and exchange to the benefit of all of the network's members.

The mission of IVETTA is creation of standards for the development and adoption of technologies that enable high-quality, accessible, and affordable transport education and training experiences. IVETTA will be enabling the next generation of Digital Learning Services, combining new forms of digital content, assessment, applications, and administrative services.

Strategic goal of IVETTA is increasing quality and safety of all mode of transport on the base of high quality standards in the life-long education and training and common network of training, industry and maintenance organizations.

Paper describes main objectives, innovation strategy focuses, main activities of future network co-operation and results, expected to be worked out by the IVETTA.

Keywords: transport, training, education

The creation of a united European transport market without restrictions or barriers to access, based on harmonised conditions of competition, is becoming one of the principal objectives of common transport policy in Europe.

Transport is quickly being acknowledged as an important human activity that will require extensive professional and academic training and disciplinary research. Accessibility manifested as mobility is an intrinsic quality of life. It must remain a postulate that by relevant academic and professional training and research the need for mobility can be made compatible with the need for sustainability.

Training and education is objectively at the meeting-point between research, technological and organisational systems.

Major features of education in the transport area are as follows:

- global character of transport as a subject of studies;
- creation of one market of transport services in Europe;
- alliance of information and telecommunication technologies with transport;
- formation of new technological directions – intelligent transport systems;
- characteristics of carriers as subjects of training in life-long learning system, comprising in their high mobility that demands new approaches in forms and methods of education differing from traditional ones.

The networked economy has placed new challenges on an organisation's ability both to innovate and to blur its traditional boundaries and structures.

In the same way as transport systems, processes and services operate in an increasing European framework, transport education and training need to change their contents taking international aspects and globalisation into consideration and move from conventional to networked environments. Even initial transport education processes at vocational and higher educational levels must be a part of these dynamic changes to enable their graduates to meet employers' needs and operate at the market. Thus transport learning is required to be flexible with respect to [1]:

- *learners* (in the widest sense) and their individual targets, motivations to learn, specific requirements and constraints according to actual and accurate business requirements,
- varying *educational needs* resulting from the learner's targets, motivations, requirements and constraints, like e. g. scope and level of knowledge, particular skills etc., and
- appropriate *educational resources* developed and used in form of modules and courses fulfilling the educational needs and helping the learner to reach the required, established goal,
- paradigm change in respect of new content delivery concepts and update the trainer's concepts.

The establishment of **I**nnovative **V**irtual **E**uropean **T**ransport **T**raining **A**gency (**IVETTA**) is one of the steps toward this direction.

The IVETTA is an educational network of persons and institutions involved in transport education and training and interested in supporting it by use of multimedia and information technologies. It focuses on enabling transport educators and trainers to introduce any kinds of educational multimedia, new technologies and common standards to their educational processes as knowledgeable consumers or well-acquainted supervisors or even to become enthusiastic multimedia developers. For this, there is required not only an appropriate technological infrastructure but also an organizational basis and culture encouraging collaboration and exchange to the benefit of all of the network's members.

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Strategic goal of IVETTA is increasing quality and safety of all mode of transport on the base of high quality standards in the life-long education and training and common network of training, industry and maintenance organizations.

The main objectives of the organisation are as follows:

1. Innovation and development of life-long learning oriented education and training in transport area on the base of exchange of good practice.
2. Familiarization of educationalists and specialists with methodology, general philosophy, innovative ideas in the area of transport education.
3. Establishment of direct and informal liaisons among transport specialists, higher school educationalists, students, employees of transport sphere of Europe.
4. Identification and search of way of problem decision arising while using standard methods for training of transport specialists.
5. Create an integrated model for defining required knowledge, skills and abilities to successfully perform job tasks. These definitions will be easily accessible and understood by users, and are used by the trainers as the template for development.
6. Implement an efficient, open and consistent process for defining and establishing priorities for customers training requirements.
7. Establish a logical, flexible and responsive training infrastructure to quickly translate field training and education requirements into easily accessible, usable and effective training materials.
8. Establish an effective evaluation process to ensure that staff is reaping the fruits of their work. Involve local supervisors in assessing the impact of training on job performance and providing feedback to the team.

To attain IVETTA strategic goal, the innovation environment must be able to create novelty and make choices. Therefore, this innovation strategy focuses on completely new topics and measures, or ones requiring a distinct change. The strategy reviews innovation activity and the required development measures via four basic choices, presented and justified in more detail as follows.

- *Innovation activity in a world without borders*: In order to join, and position itself within, global competence and value networks, IVETTA must actively participate and exert influence and be internationally mobile and attractive.
- *Demand and user orientation*: Innovation steered by demand, paying attention to the needs of customers and consumers in the operations of the public and private sector alike, requires a market with incentives and shared innovation processes between users and developers.
- *Innovative individuals and communities*: Individuals and close innovation communities play a key role in innovation processes. The ability of individuals and entrepreneurs to innovate, and the presence of incentives are critical success factors of the future.
- *System approach*: Exploitation of the results of innovation activities also require broad-based development activities aiming at structural renewal and determined management of change.

The organisation is live due to the fact that changes in transport area connected to extension of the European Union, globalisation, multi-modality of transport operations and modernization of transport technologies demand adequate changes in the process of training and re-training of transport specialists and development of new forms and methods.

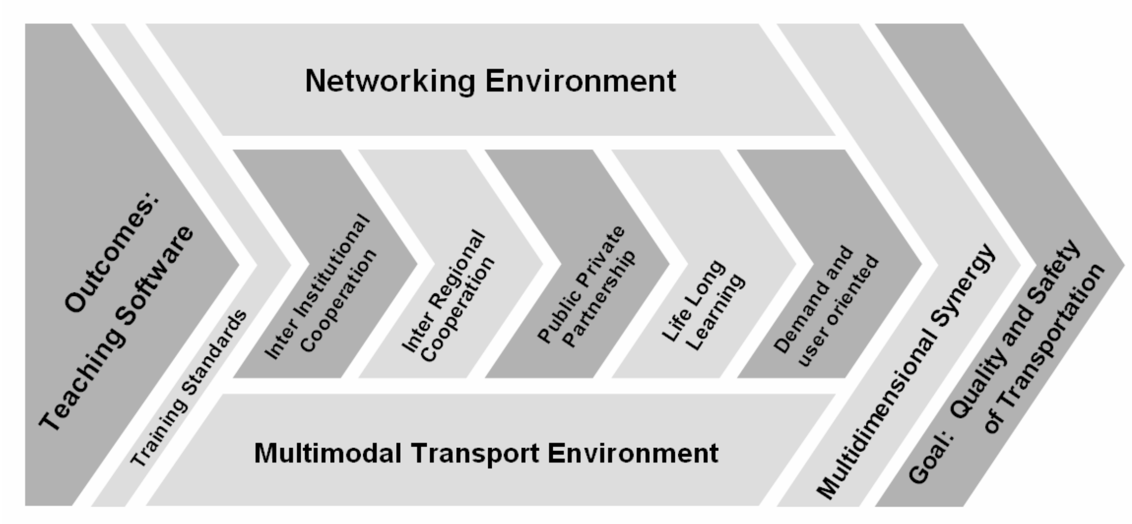

Figure 1. Main principals of IVETTA operation

There has been suggested discussing of a wide range of issues in the following directions at the frames of the project [2, 3]:

- New technologies in transport education
- Learning of new technologies in transportation (intelligent transport systems, transport telematics, etc.)
- Case study – situational learning of characteristics of transport operations in various countries and international logistic units
- Peculiarities of distant learning (e-learning) in the process of transport equipment studies
- Concept of life-long learning in conditions of transport sphere globalisation

- Standardization of approaches in content and methodology of transport education in conditions of one widening European market
- Content and method of education and training concerning the issues of multi-modal and combined transport
- Creation of educational networks between educational establishments of one country and educational establishments of different countries (regional) with the aim of increase of the competence of educational processes in the area of international transportation
- Integration of learning methods according „learning on demand strategies" into the actual working process
- Development and integration of new train the trainer concepts according life- long learning concepts.

The main activities of such future network co-operation may be as follows:

- identify centres of excellence in Europe and their type of competence,
- define a common "knowledge data base" and determine the way of distributing and maintaining it,
- define knowledge needs and gaps for training and educating for up-to-date transport in Europe,
- good practices for training and education in transport,
- demonstrate the effectiveness of the good practice guidelines by example,
- create a competence centre for new partners in joining the network,
- understand the existing experiences in the world, establishing exchanges as appropriate,
- create and deploy performance based partnerships.

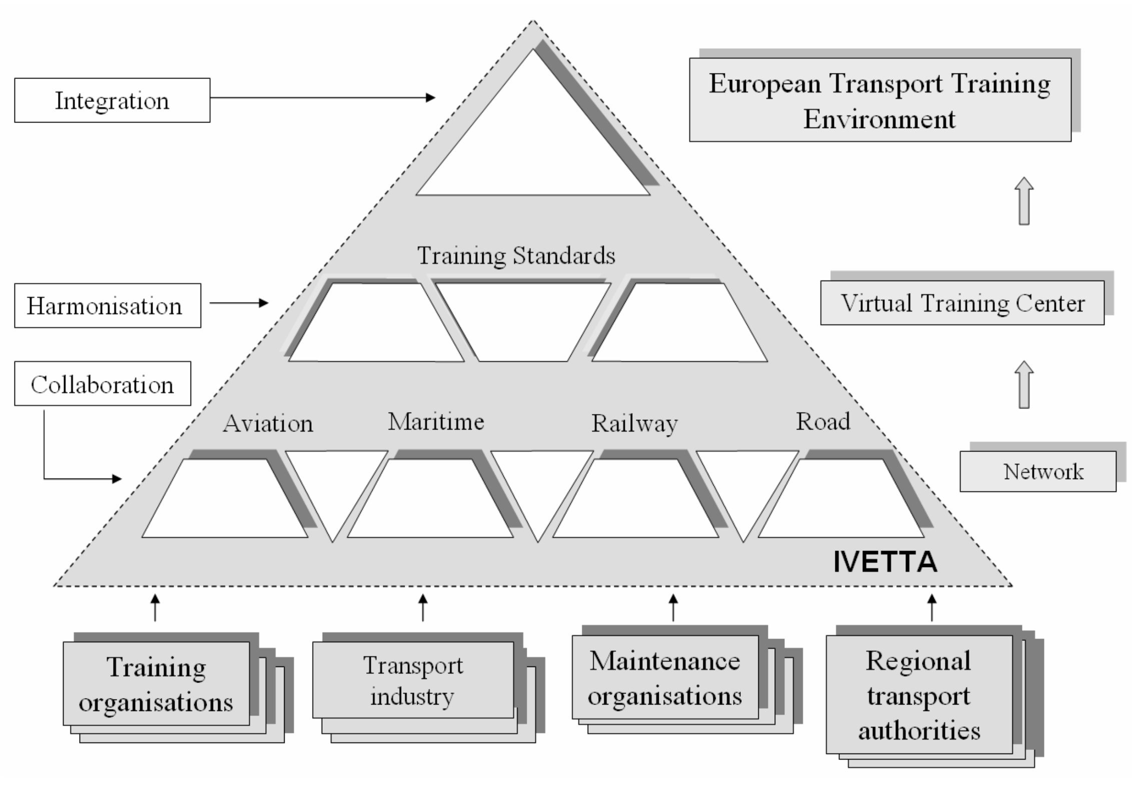

Figure 2. Main Phases of IVETTA Development

IVETTA will expose the users to innovative training process and will allow for the implementation of a new type of relationship between training organisations, transport operators, maintenance organisations and transport policy-markers. The main tasks of IVETTA will be the following [4]:

- To develop a new specialised training system based on knowledge and good-practices in the management of high-tech transport business and to disseminate it across the Europe and across the different business branches and transportation modes through a multinational training network, seminars and learning materials.
- To develop, test and apply on-line training methodology for standard and personalised (self-training and tailor-made) courses based on a case studies database, identified needs, knowledge and experience of the partners, and constantly maintained feed back from the beneficiaries and on business trajectory based models.
- To create an easy-to-learn virtual environment for continued professional development of entrepreneurs and managers of innovative and high-tech transport companies. It will be realised through setting up an *e*-Learning site and providing a set of on-line services – group standard or tailored-made open classrooms, on-line self-training sessions, group discussions, multimedia supported sessions, conference and chat sessions, frequently asked questions, publications and bibliography database.

The results, expected to be worked out by the IVETTA can be grouped as follows:

- Methodologies, models, guidelines, curricula. In the initial stage the partners will elaborate and apply a new methodology (manual) for identification of the target groups' training needs. A unified training methodology (manual) will be a core of a new training system. The other element of this system will be on-line learning methodology. Design of the database model and its updating is also expected to be finished at the end of the first stage. The system will also consist of a methodology (manual) for study, analysis and selection of case studies and their subsequent use in the training process. Manual for consultants/trainers and their certification for the needs of the project is a key product in this group. The unified model will be further refined in two directions – standard and personalised models with new training curricula. Training guidelines will be produced as an explanation of a competence based approach in training.
- Products, software, and tools. Main result is web portal, hosted and maintained by one partner and national sections. Web facilities are databases for consultants, cases, and courses and teaching materials, which are organised in two parts – common and local (on national language). Virtual classroom is a facility, which integrates the on-line methodology for training with the tool for courses design: for trainers, for trainees and forum, poll and chat tool. Internet web portal will ensure communication channel between trainers, consultants and users.
- Materials, workshops, seminars. Multimedia as well as printed materials will be disseminated, several workshops and seminars in the course of the project will be organised. Considerable attention will be given to events that will attract public attention to the project – demonstrations, interviews and articles in specialized magazines.
- Standards for a highly sophisticated course of the trainer's model based on performance partnerships and business trajectory demands.

The process of designing such a network for transport education and training must involve a tight relationship between educational establishments as consultants and transport companies as customers in combining theory and practice, starting with analysis and evaluation of results and ending with achievement of the expected by-products.

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Transport and Telecommunication, 2009, Volume 10, No 2, 16–25
Transport and Telecommunication Institute, Lomonosova 1, Riga, LV-1019, Latvia

RELIABILITY OF FATIGUE-PRONE AIRFRAME. INSPECTION PROGRAM CONTROL

Yury Paramonov, Andrey Kuznetsov

Aviation Institute, Riga Technical University
Lomonosova Str. 1, Riga, LV-1019, Latvia
Ph.: +371 67255394. Fax: +371 67089990
E-mail: yuri.paramonov@gmail.com, andreyk@hotbox.ru

Algorithm of inspection program development and control using theory of Markov chains and p-set function definition on the base of processing of approval lifetime test result is discussed.We make assumption that some Structural Significant Item (SSI), the failure of which is the failure of the whole system, is characterized by a random vector (r.v.) (T_d, T_c), where T_c is critical lifetime (up to failure), T_d is service time, when some damage (fatigue crack) can be detected. We suppose also that a required operational life of the system is limited by the so-called Specified Life (SL), $\boldsymbol{t}_{SL}$, when system is discarded from service. Some examples are given.

Keywords: inspection program, Markov chains, reliability

1. Introduction. Failure Probability Calculation Using Theory of Markov Chains

This paper is development of previous author papers [1,2,3]. Airframe inspection program control planning can be constructed using theory of Markov Chains. For this purpose the inspection program is presented as a process of several states: first $n+1$ states, $E_1, E_2, ..., E_{n+1}$, represent aircraft service in the appropriate interval between two consequent inspections, service time $t \in [t_{i-1}, t_i)$, $i = 1,2,...,n+1$, $t_0 = 0$, $t_{n+1} = t_{SL}$, (an aircraft is discarded from service at specified life, t_{SL}, even if there are no cracks discovered by the time moment t_{SL}), while three additional states, $E_{n+2}, E_{n+3}, E_{n+4}$, represent aircraft withdrawal from the service due to (1) the successful end of service when the specified life period is over (E_{n+2}= SL-state), (2) due to fatigue failure (E_{n+3}=FF-state) and (3) due to discovery of a crack (E_{n+4}=CD-state). Let the probability of crack detection during the inspection number *i* at time moment t_i is denoted as v_i; probability of failure in service time interval (t_{i-1}, t_i) as q_i; and probability of absence of above-mentioned events as u_i. Since these three cases form a complete set $u_i + v_i + q_i = 1$. In our model we also assume that there is an inspection at t_{SL} also. This inspection at the end of (n+1)-th interval does not change the reliability but it should be done in order to know the state of aircraft (there is fatigue crack or there is not fatigue crack). The transition probability matrix of this process can be composed as it is presented on Fig**Error! Reference source not found.**ure 1.

	E_1	E_2	E_3	…	E_n	E_{n+1}	E_{n+2} (SL)	E_{n+3} (FF)	E_{n+4} (CD)
E_1	0	u_1	0	…	0	0	0	q_1	v_1
E_2	0	0	u_2	…	0	0	0	q_2	v_2
…	…	…	…	…	…	…	…	…	…
E_{n-1}	0	0	0	…	u_{n-1}	0	0	q_{n-1}	v_{n-1}
E_n	0	0	0	…	0	u_n	0	q_n	v_n
E_{n+1}	0	0	0	…	0	0	u_{n+1}	q_{n+1}	v_{n+1}
E_{n+2} (SL)	0	0	0	…	0	0	1	0	0
E_{n+3} (FF)	0	0	0	…	0	0	0	1	0
E_{n+4} (CD)	0	0	0	…	0	0	0	0	1

Figure 1. The transition probability matrix

In this paper we suppose the exponential approximation of fatigue crack growth function when fatigue crack size, $a(t)$, is described by equation $a(t) = a_0 \exp(Qt)$, where $a_0 = a(0)$ is equivalent initial crack size[4,5]. Despite of all simplicity, this formula shows us rather comprehensible results in interval (T_d, T_c), where T_c is critical lifetime (up to failure), T_d, is service time, when some damage (fatigue crack) can be detected with probability equal to unit:

$$T_d = (\ln a_d - \ln a_0)/Q = C_d / Q, \; T_c = (\ln a_c - \ln a_0)/Q = C_c / Q,$$

where a_d is a crack size, when the probability to discover it is equal to unit, a_c is a crack size, which corresponds to the maximum residual strength of an aircraft component allowed by special design regulation.

We see that parameters C_c and C_d can be derived each from another:

$$C_d = C_c - \delta, \text{ where } \delta = \ln a_c - \ln a_d = \ln \frac{a_c}{a_d},$$

If δ is some constant then actually for considered model of fatigue crack growth the distribution of r.v. (T_d, T_c) is defined only by two random variables (parameters of fatigue crack growth): C_c and Q. Let us denote $X = \ln Q$ and $Y = \ln C_c = \ln(\ln(a_c/\alpha))$. From the analysis of the fatigue test data it can be assumed, that the logarithm of time required the crack to grow to its critical size (logarithm of durability) is distributed normally. It comes from the additive property of the normal distribution that $\ln T_c$ could be normally distributed either if both $\ln C_c$ and $\ln Q$ are normally distributed. So we suppose that random variables $X = \log(Q)$ and $Y = \log(C_c)$ have normal distributions with unknown mean values θ_{0X}, θ_{0Y} and known standard deviations and correlation coefficient $\theta_{1X}, \theta_{1Y}, r$. We suppose that if in interval (T_d, T_c) some inspection will be made then fatigue failure will be eliminated.

These assumptions allow calculating of

$$\begin{aligned}
&u_i = P(T_d > t_i \mid T_d > t_{i-1}) = P(Q < C_d / t_i) / P(Q < C_d / t_{i-1});\\
&q_i = P(t_{i-1} < T_d < T_C < t_i \mid t_{i-1} < T_d) =\\
&\begin{cases} 0, \quad \text{if } t_{i-1} C_c / C_d > t_i, \\ P(C_c / t_i < Q < C_d / t_{i-1}) / P(Q < C_d / t_{i-1}), \; \text{if } t_{i-1} C_c / C_d \le t_i, \end{cases};\\
&v_i = 1 - u_i - q_i;
\end{aligned} \qquad (1)$$

Unfortunately, corresponding integrals are not expressed by elementary functions, but if it is assumed that C_c and C_d are some constants then we have

$$u_i = a_i / a_{i-1}, \; q_i = \max(0, (a_{i-1} - b_i)/(1 - a_{i-1})),$$

where $a_i = \Phi(\ln(C_d / t_i) - \theta_0)/\theta_1)$, $b_i = \Phi(\ln(C_c / t_i) - \theta_0)/\theta_1)$, $\Phi(.)$ is distribution function of standard normal variable. It is necessary to mention, that if we consider a park of N aircraft of the same type and if we are interested to know the probabilities of the failure of at least one aircraft or crack discovery in at least one aircraft of the park then instead of q_i, u_i and v_i we should use $q_{i,N} = 1 - (1 - q_i)^N$, $u_{i,N} = (u_i)^N$ and $v_{i,N} = 1 - q_{i,N} - u_{i,N}$. Let us denote the corresponding matrix by symbol P_N. The structure of considered matrices can be described in the following way (Figure 2):

$$\begin{array}{|c|c|} \hline Q & R \\ \hline 0 & I \\ \hline \end{array}$$

Figure 2. Sub-matrices of transition probabilities matrix

Here I is matrix of identity corresponding to absorbing states, 0 is matrix of zeros. Then matrix of probabilities of absorbing in different absorbing states for different initial transient states is defined by formula

$$B = (I - Q)^{-1} R \; . \qquad (2)$$

First row of the matrix B defines the probabilities of absorption in states SL, FF, CD if initial state is E_1. Particularly, $B(1,2)$ defines the failure probability for new aircraft which begin operation in first interval. For the park of N aircraft, $B_N(1,2)$ is a probability of at least one aircraft failure in this park. The following rows of the matrix B and B_N define the same probabilities for different initial states: for aircraft which begins operation in different time intervals. So if, for example, all N aircraft of the considered fleet begin operation in first interval simultaneously then the failure probability of at least one aircraft in the fleet is equal to

$$p_f = aB_N b \, , \qquad (3)$$

where vector row $a = (1,0,...,0)$ means that all aircraft begin operation in first interval (state E_1), vector column $b = (0,1,0)'$.

2. Failure Probability Calculation Using Markov Chains Theory for Specific Inspection Program Control

Markov Chains theory is especially attractive to model various scenarios of switching to the alternative inspection programs when the certain event takes place. In this section we consider example of the following specific strategy. Let in the fleet at the beginning of service there was N aircraft. When the first crack is discovered in the fleet we make repair of corresponding aircraft (so that its failure in following operation will be eliminated) and double the frequency of inspections of the remaining (N-1) aircraft. And suppose that in following we will not change the inspection program for any aircraft.

Here we consider the failure probability calculation in special case, when in initial inspection program we have only two inspections. For this simple example after fatigue crack discovery the remaining inspection intervals for the others aircraft are parted into two parts. The decision to double inspection number (or, which is the same, decrease two times the inspection interval) graphically looks as it is shown on Figure 3.

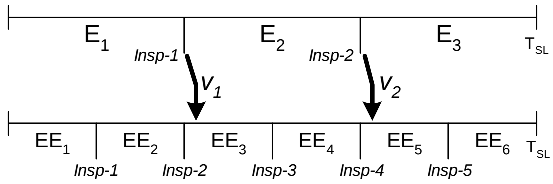

Figure 3. Switching to double inspection frequency for initial two-inspection program

As we can see, this decision is equivalent to continuation of service (of every specific aircraft) in accordance with inspection plan based on 5 inspections. The corresponding transformation of initial states graph is shown on Figure 4.

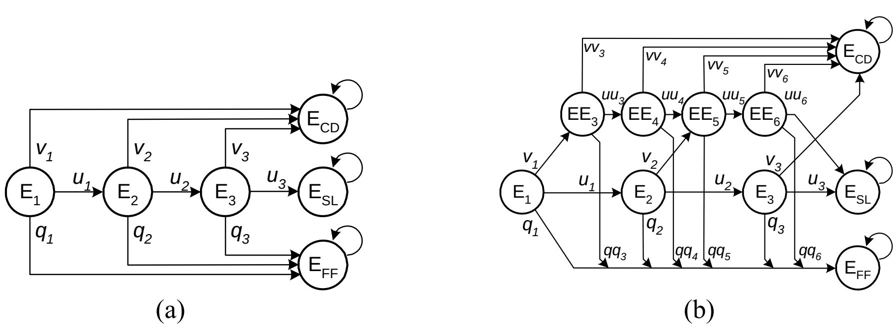

Figure 4. Ordinary two-inspection strategy state graph (a) for initial two-inspection program and switching to the double inspection frequency state graph (b).

For failure probability calculation it is convenient to introduce new “quasi-absorbing” states *CD*1 and *CD*2 (see Figure 5), corresponding to states EE_3 and EE_5 (see Figure 4.b) of the initial matrix. The states CD1 and CD2 are quasi-absorbing states corresponding to “absorption” of “initial process” at the inspection 1 and inspection 2. But really these are the points of beginning of “new” processes with different inspection programs.

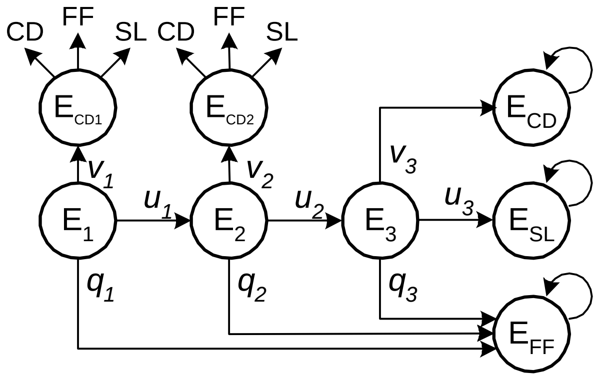

Figure 5. Switching to the double inspection frequency reduced state graph for initial two-inspection program

Corresponding transition probability matrix is shown on Figure 6.

	E_1	**E_2**	**E_3**	**E_4 (SL)**	**E_5 (FF)**	**E_6 (CD)**	**E_7 (CD 1)**	**E_8 (CD 2)**
E_1	0	$u_{1,N}$	0	0	$q_{1,N}$	0	$v_{1,N}$	0
E_2	0	0	$u_{2,N}$	0	$q_{2,N}$	0	0	$v_{2,N}$
E_3	0	0	0	$u_{3,N}$	$q_{3,N}$	$v_{3,N}$	0	0
E_4 (SL)	0	0	0	1	0	0	0	0
E_5 (FF)	0	0	0	0	1	0	0	0
E_6 (CD)	0	0	0	0	0	1	0	0
E_7 (CD1)	0	0	0	0	0	0	1	0
E_8 (CD2)	0	0	0	0	0	0	0	1

Figure 6. The matrix $P_N IP^0$ corresponding to the Figure5.

As in previous case the matrix of probabilities of absorption in different absorbing states for different initial transient states is defined by formula

$$B = \left(I - Q\right)^{-1} R .$$

It is obvious that now we have the random inspection program (IP), which has in fact three possible realizations:

$IP^0 : \{t_1, t_2, t_3\}$,
$IP^1 : \{t_1, (t_1 + t_2)/2, t_2, (t_2 + t_{SL})/2, t_{SL}\}$,
$IP^2 : \{t_1, t_2, (t_2 + t_{SL})/2, t_{SL}\}$.

The probability of each scenario to realize depends on the probability to discover a crack during the inspections of the basic scenario. Probability of IP^1 is equal to probability of absorption in state CD1, $p(CD1)$. Probability of IP^2 is equal to probability of absorption in state CD2, $p(CD2)$. Probability of IP^0, $p(IP^0)$, is equal to 1- $p(CD1)$ - $p(CD2)$. For IP^0 the corresponding list of states in corresponding Markov chain is defined in Figure 4.a: E_1, E_2, E_3, SL, FF, CD. For IP^1 it is defined in Figure 4.b: E_1, EE_3, EE_4, EE_5, EE_6, SL, FF, CD. For IP^2 it is defined in Figure 4.b also: E_1, E_2, EE_5, EE_6, SL, FF, CD.

For every scenario, using already described approach we can calculate the probability of failure and then to calculate total probability of failure of at least one aircraft in a fleet:

$$p_f = B_N IP^0(1,2) + B_N IP^0(1,4)(1-(1-B_1 IP^1(2,2))^{N-1}) \\ + B_N IP^0(1,5)(1-(1-B_1 IP^2(3,2))^{N-1}) , \quad (4)$$

where $B_N IP^r(i,j)$ is (i, j)-th element of matrix B_N for IP^r inspection program, $r = 1,2$, for fleet with N aircraft. Rows of matrix $B_N IP^1$ correspond to transient states: E_1, EE_3, EE_4, EE_5, EE_6. Columns correspond to absorbing states: SL, FF and CD. For matrix $B_N IP^2$ rows corresponding to transient states are: E_1, E_2, EE_5, EE_6. Columns correspond to the same absorbing states: SL, FF and CD. Matrix P for inspection program IP^0 can be seen on Figure 1 if $n = 2$. Structure of the matrix $B_N IP^0$ is shown on Figure 7.

	E_4 (SL)	**E_5** (FF)	**E_6** (CD)	**E_7** (CD 1)	**E_8** (CD 2)
E_1					
E_2					
E_3					

Figure 7. Structure of the matrix $B_N IP^0$

3. Failure Probability Calculation for Inspection Program Control in General Case

In general case in the initial IP there are n inspections and in corresponding matrix of transition probabilities, see Figure 8, there are $(n+1)$ transient and (n +3) absorbing states: three initial absorbing states (SL, FF and CD) and n additional quasi-absorbing states

	E_1	E_2	$\cdots$	E_{n+1}	E_{SL}	E_{FF}	E_{CD}	E_{CD1}	$\cdots$	E_{CDn}
E_1	0	u_{1N}	$\cdots$	0	0	q_{1N}	v_{1N}	0	$\cdots$	0
E_2	0	0	$\cdots$	0	0	q_{2N}	0	v_{2N}	$\cdots$	0
$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$
E_{n+1}	0	0	$\cdots$	0	$u_{(n+1)N}$	$q_{(n+1)N}$	0	0	$\cdots$	$v_{(n+1)N}$
E_{SL}	0	0	$\cdots$	0	1	0	0	0	$\cdots$	0
E_{FF}	0	0	$\cdots$	0	0	1	0	0	$\cdots$	0
E_{CD}	0	0	$\cdots$	0	0	0	1	0	$\cdots$	0
E_{CD1}	0	0	$\cdots$	0	0	0	0	1	$\cdots$	0
$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$
E_{CDn}	0	0	$\cdots$	0	0	0	0	0	$\cdots$	1

Figure 8. Modified transition probability matrix

The optimal changes of initial inspection program can be founded by analysis of new information realised after discovering of fatigue crack. Discovery of fatigue crack can give us additional observation of fatigue crack possible trajectory and, as a result, more precise estimate of parameter θ . In simplest case we can assume that now we have observation of two realizations of fatigue crack, but really all depends on both the technology of inspection and algorithm of its result analysis. This is subject of special investigation.

Thus, there are n possibilities to switch to the new inspection program, generating a set of ($n+1$) realizations (or scenarios) of the random inspection program, $\{IP^0, IP^1, IP^2, ..., IP^n\}$. Let $b = \left\{ b_0 , b_1 , b_2 , \ldots b_n \right\}$ is a vector of corresponding probabilities: b_i is a probability to discover a crack during i^{th} inspection in accordance with initial program, $i = 1,\ldots,n$, b_0 is probability of realization of initial inspection program IP^0 (it is a probability of non-discovery of any crack at any first n inspections or probability to be absorbed in states SL, FF or CD in accordance with the initial inspection program)

$$b_i = B_N IP^0(1,3+i)\,,\; i = 1,\ldots,n\,,\; b_0 = 1 - \sum_{i=1}^{n} b_i\,. \tag{5}$$

In considered in section 2 example : $b_1 = B_N IP^0(1,4)$, $b_2 = B_N IP^0(1,5)$. The total failure probability of the random inspection program can be presented as a sum of at least one aircraft failure probabilities of all scenarios multiplied by the probabilities of these scenarios to realize:

$$p_f = p_{f0N} + \sum_{i=1}^{n} \left(b_i \cdot (1 - (1 - p_{fi})^{N-1}) \right), \tag{6}$$

where p_{f0N} is failure probability of at least one aircraft in park of *N* aircraft with the service in accordance with initial inspection program; p_{fi}, $i = 1,\ldots,n$, is a probability of failure of one aircraft with the inspection program chosen after crack discovery at i-th inspection of initial inspection program.

Let us note, that the new inspection program is implemented for every of (*N*-1) aircraft with independent service (this mean that now after discovery of any new fatigue crack in any of (*N*-1) aircraft the program of inspection of others aircraft will not be changed). The value of p_{fi} is defined by equation (3) but using vector $a=(0,...,0,1,0,...,0)$, where "1" is for the (i+1)-th state of the new MC, corresponding to the discovery of fatigue crack at the i-th inspection of initial inspection program. In considered in section 2 example: $p_{f0}=B_N IP^0(1,2)$, $p_{f1}=B_1 IP^1(2,2)$ and $p_{f2}=B_1 IP^2(3,2)$. (Remind, list of transient states for IP^1 is: E_1, EE_3, EE_4, EE_5, EE_6; for IP^2 it is E_1, E_2, EE_5, EE_6. List of absorbing states is the same in both cases : SL, FF and CD).

4. Inspection Program Development

Usually in Aircraft Design Bureau (ADB) documents the sequence $(t_1,...,t_n)$ is defined by equation $t_i = t_1 + (i-1)(t_{SL}-t_1)/n$, $i=1,2,...,n+1$, with specific choice of t_1. Then we should choose only t_1 and n. Just now for simplicity purpose we put $t_1 = t_{SL}/(n+1)$ (in general case t_1 can be chosen, for example, as parameter-free p-bound for T_c [1], or we can try to get minimum of expectation value of n at fixed required reliability, etc). Here we consider only this ADB simple rule. But this corresponds not only to the development of inspection program without control but and to correction of initial inspection program (and really, to the development of new inspection program with new "initial" information) after discovery of some fatigue crack. The difference is only in "initial" state and in the distribution of parameter estimate, because now we have observation of trajectory of at least two fatigue cracks. (In simplest case of one-dimensional unknown parameter we can assume that now we have sample of two observations of r.v. with the same cdf).

For the only occurring once choice of inspection number the probability of failure will be function of θ and n. We denote it by $p_f(\theta,n)$. Probability $p_f(\theta,n)$ can be non-monotonous function of n if at increasing of n relocation of inspection time moments takes place. But we consider only such strategies of the choice of the sequence of inspection time moment $\{t_i,\ i=0,1,2,...,n\}$ that for all $\theta\in\Theta_0$ and for enough small ε there is minimal inspection number n such that $p_f(\theta,k)\le\varepsilon$, for all $k\ge n$, $k=1,2,...$. and $p_f(\theta,n)$ monotonously decreases if n increases beyond of this value. This n is defined by equation:

$$n(\theta,\varepsilon)=\min(k : p_f(\theta,k)\le\varepsilon \text{ for all } k\ge n,\ k=1,2,...). \quad (7)$$

For the case when $p_f(\theta,n)$ is monotonous function of n a schematic diagram of the solution of the equation $p_f(\theta,n)=\varepsilon$ and calculation of the function $n(\theta,\varepsilon)$ is shown on Figure 9.

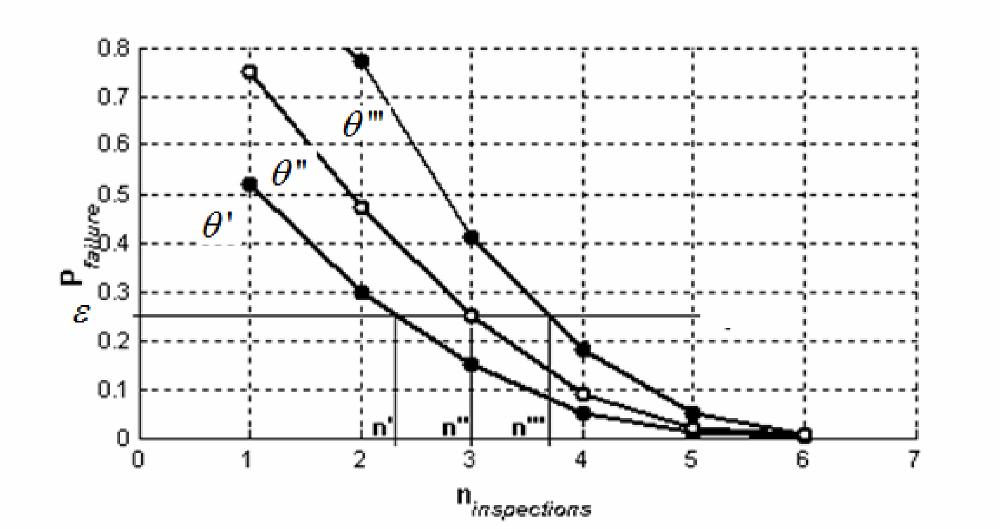

Figure 9. Choice of number of inspections as function of allowed failure probability for different parameter θ

But a true value of θ is unknown. Only observation of its estimate, a random variable $\hat{\theta}$, is known. So $\hat{n} = n(\hat{\theta}, \varepsilon)$ and $\hat{p}_f = p_f(\theta, \hat{n})$ are random variables also.

Let us define the random variable

$$\hat{p}_{f0} = \begin{cases} p_f(\theta, \hat{n}), & \hat{\theta} \in \Theta_0, \\ 0, & \theta \notin \Theta_0. \end{cases} \tag{8}$$

For this type of strategy (algorithm of choice of n) the mean probability of fatigue failure $w(\theta, \varepsilon) = E_\theta(\hat{p}_{f0})$ is a function of θ and ε. If for limited t_{SL} it has a maximum, depending on ε then the choice of maximal value of $\varepsilon = \varepsilon^*$ for which $w^* = \max_\theta w(\theta, \varepsilon) \le 1 - R$, where R is required reliability, and the strategy, which defines the inspection number $n = n(\hat{\theta}, \varepsilon^*)$ is the choice of such strategy (decision function) for which required reliability R is provided independently of unknown θ. (Remark. The same approach can be used for any other strategy for nomination the sequence of inspection time moments if this strategy is defined by some parameter, ν, which instead of n defines the sequence ($t_1, ..., t_{n(\nu)}$) in such a way that for all $\theta \in \Theta_0$ and for any ε, $0 < \varepsilon < 1$, there is parameter, ν, defined by equation (7), where ν should be read instead of n. For example, we can choose intervals between inspections under condition of constancy of conditional probability of failure in every interval under condition that in previous intervals fatigue crack did not appear).

Control *IP* is defined by vector $(n, n_1, ..., n_n)$, where n is inspection number for initial program (it is chosen for "initial" program in accordance with equation (6)), n_i, $i = 1, \ldots, n$, is an inspection number for every "second part" of operation (after the discovery of fatigue crack at i-th inspection of initial *IP*)). If, in the simplest case, for every "absorbing state" CDi, we chose n_i again under condition that in remaining operating time the probability of failure p_{fi} does not exceed some fixed value, which is some known function of ε, $\varepsilon_n(\varepsilon)$, then the total probability of failure, p_f, will be only function of θ and ε, $p_{f\varepsilon}(\theta, \varepsilon)$. Remind, that following calculation of $E_\theta(p_{f\varepsilon}(\hat{\theta}, \varepsilon))$ this time should be made using not only the cdf of initial estimate, $\hat{\theta}$, but taking into account that this estimate is corrected after the discovery of fatigue crack. The procedure of this correction is a subject of special investigation. Here we underline only that the core of this problem solution is the solution for the simple *IP* of the equation (6), in which instead of $p_f(\theta, n)$ should be used

$$p_{fi} = a_i B_1 b \tag{9}$$

with the vector $a_i = (0, ..., 0, 1, 0...)$, where unit is for ($i$+1)-th component but again vector column $b = (0,1,0)'$. So in this paper we consider only numerical example of the choice of n for the simple *IP* [3].

5. Numerical examples

It is clear that before calculation of p_f and choice of inspection program we should made calculation of p_{f0N}, p_{fi}, $i = 1, \ldots, n$, p_{fi}, $i = 1, \ldots, n$, and $b = \{ b_0, b_1, b_2, \ldots b_n \}$. As it was told already, here we consider only calculation of p_{f0N} for N =1 and choice of initial number of inspections. Calculation after discovery fatigue crack should be made in similar way (should be changed only a priory distribution (vector a) and distribution of parameter estimate because now we have observations of two fatigue cracks.

As it was tolled already also, we suppose that random variables $X = \log(Q)$ and $Y = \log(C_c)$ have normal distributions with unknown mean values θ_{0X}, θ_{0Y} and known both standard deviations and correlation coefficient, $\theta_{1X}, \theta_{1Y}, r$. In considered example we suppose to have event $\hat{\theta} \notin \Theta_0$ and we will return the considered project to redesign if required number of inspections exceeds n_R=5 or value of

$\hat{t}_c = C_c / Q$, estimate of mean time to failure, $E(T_c)$, using result of initial full scale fatigue test, lesser than t_{SL} =40000 (flights). For this examples we assume that only one full-scale test (before corresponding aircraft park service beginning) had been performed and we have observation of just one single crack growth and corresponding estimates: $\hat{\theta}_{0X} = \ln Q = -8.588527$, $\hat{\theta}_{0Y} = \ln C_c = 1.905525$. These estimate we use later for the choice of initial inspection number. But first, using Monte Carlo method for modelling of possible another estimates, of we make calculation of the surface $w(\theta,\varepsilon) = E_\theta(\hat{p}_{f0})$ for all parameters in some set of θ=(θ_{0X}, θ_{0Y}) in the closeness of the point ($\hat{\theta}_{0X}, \hat{\theta}_{0Y}$). On the Figure 10 the calculation results of $w(\theta,\varepsilon) = E_\theta(\hat{p}_{f0})$ for ε =0.001 is presented (in this examples we use inspection program with special choice of t_1 and evenly distributed time moments between t_1 and t_{SL}; the time moment of the first inspection is defined by equation $\ln t_1 = \ln t_{SL} - 5 \cdot \theta_{1X}$; the detectable and critical crack sizes are $a_d = 20mm$, $a_c = 237.84mm$). Complex form of the function $w(\theta,\varepsilon)$ is defined by the fact that $p_f(\theta,n)$ might be non-monotonous function of n. For relatively small n, $p_f(\theta,n)$ can grow with the increase of n. The reason of such "strange" effect comes from the fact of inspection time moments relocation with the change of n.

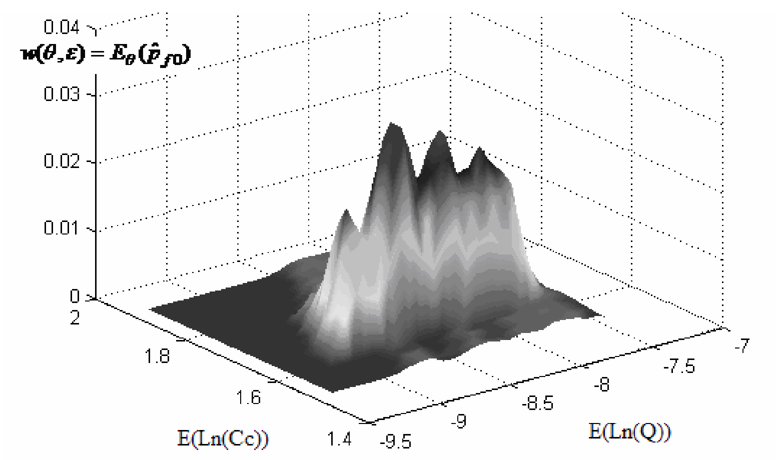

Figure 10. Function $w(\theta,\varepsilon) = E_\theta(\hat{p}_{f0})$ for ε =0.001

This time the maximum values of the function $w(\theta,\varepsilon)$ are equal to 0.030990. If we repeat this calculations using various values of failure probability ε we will get a set of "surfaces" $w(\theta,\varepsilon) = E_\theta(\hat{p}_{f0})$ and function $w^*(\varepsilon) = \max_\theta w(\theta,\varepsilon)$, see Figure 11.

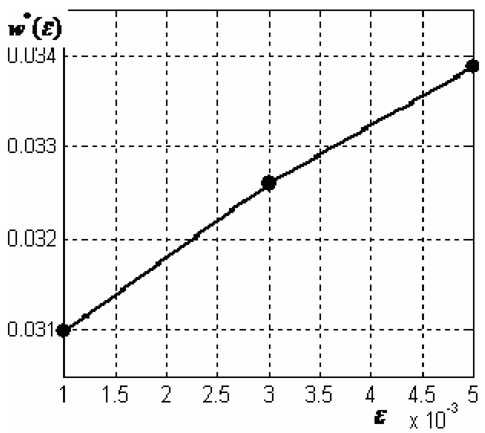

Figure 11. Numerical example: The function $w^*(\varepsilon)$

Using this function we see, that to ensure the probability of failure not exceeding, for example, w^* = 0.0326 for the choice of n^*, required number of inspections for our inspection program, we should use ε^*=0.003 (it is worth to mention that w^* is ten times higher than ε^*!). Remind, that $n^* = n(\hat{\theta},\varepsilon^*) = \min(k : p_f(\hat{\theta},k) \le \varepsilon^*$ for all $k \ge n,\ k = 1,2,...)$. In our example $\theta = \hat{\theta}$=($\hat{\theta}_{0X}, \hat{\theta}_{0Y}$)= =($-8.588527$, 1.905525) and the required number of inspections n^*=5 (it is worth to mention that $n(\hat{\theta}, 0.0326) = 4$).

For control *IP* similar calculations should be made for every quasi absorbing state (with specific cdf of parameter estimates). Then corresponding p_{f0N} and vector $b = \{ b_0, b_1, b_2, \dots b_n \}$ should be calculated. And again remind that all these calculation should be made for all parameters in some set of θ=(θ_{0X}, θ_{0Y}) in the closeness of the point **(**$\hat{\theta}_{0X}, \hat{\theta}_{0Y}$**).**

6. Conclusions

It is shown that using Markov chains theory a development of controlled inspection program of fatigue-pron airframe can be made. Using of minimax approach we can provide required reliability of the fleet and in the case when we do not know true parameter of fatigue crack growth but only observation of limited number fatigue cracks in approval full-scale airframe fatigue test. The offered mathematical model allows taking into account the observation of fatigue crack in operation during planned inspection also.

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Transport and Telecommunication, 2009, Volume 10, No 2, 26–32
Transport and Telecommunication Institute, Lomonosova 1, Riga, LV-1019, Latvia

STATISTICAL ANALYSIS OF THE RELATIONSHIP BETWEEN PUBLIC TRANSPORT ACCESSIBILITY AND FLAT PRICES IN RIGA

Dmitry Pavlyuk

Transport and Telecommunication Institute
Lomonosova Str. 1, Riga, LV-1019, Latvia
Ph.: +371 29958338. E-mail: Dmitry.Pavlyuk@tsi.lv

The relationship between public transport accessibility and residential land value is a point of interest of many recent researches. A hedonic price regression model, widely used in this research area, has one very important shortcoming – it calculates an “average” influence of factors on land value in the analysing area. Usually spatial effects present in data, and the influence of public transport accessibility can be distributed over the area non-uniformly.

In this study we apply a comparatively new modification of the regression model – geographically weighted regression – to examine the relationship between public transport accessibility and residential land value (in a form of rent and sell prices) in Riga. The proposed method allows taking into account spatial effects present in the relationship.

We use information about geographical locations of urban public transport stops and routes to calculate a level of transport accessibility.

Together with the transport accessibility level and a common set of property-specific parameters (floor area, number of rooms, etc.) we consider additional hedonic properties of a flat location such as distances to supermarkets, higher schools and natural attractors like large parks, the river, and the seaside.

Keywords: geographically weighted regression, hedonic price model, public transport accessibility

1. Introduction

Nowadays public transport is one of the main components of a city infrastructure. Improvements of public transport routes are presented in almost all city development plans ([1]), and the main reason for it is a classical assumption about a positive relationship between the quality of the public transport infrastructure and land value. Good quality of public transport increases people’s mobility, improves living conditions in city outskirts, raises business activities, and, as a result, makes the land value higher.

Classically the land value can be considered from two main view points – business activities and residential living. In this research we use the second approach and consider the residential land value in two forms – flat sell prices and flat rent prices. Both sell and rent prices indicate the residential land value, but with different aspects. Sell prices shows the long-term land value and influenced mostly by stable factors like living utilities and public transport around the house. Rent prices are significantly oriented by a number of temporary habitants like tourists and students, and that’s why influenced by location factors – distances to tourist attractions, sea/river sides, and higher educational institutes. The influence of tourists on rent prices are especially significant for Riga, where the number of tourists arriving every quarter is similar to the total city population, and every third tourist chooses a non-hotel accommodation.

The usual econometric approach widely used ([2]) in this area is a hedonic price regression model. The hedonic regression can be formulated as:

$$Price = \mathrm{F}(PropertyFactors, LocationFactors, TransportFactors) + \varepsilon,$$

where the dependent variable *Price* is explained by three sets of factors – property, location, and transport characteristics [3].

A usual regression model shows how factors influence a dependent variable *in average*. This is good for understanding of dependencies in cross-sectional non-spatial data, but this is a huge disadvantage in a spatial case like housing data. As an example let us consider the dependence between a flat floor area and a flat price. If we estimate the usual regression in this case, we will receive an average price per square metre in a city. But this number will not be useful in case of significant deviations of this indicator in the city parts; the average value will be bad approximation for every particular flat. The obvious way to solve this problem is including district-specific dummy variables into the regression (or cross-dummy variables as products of district-specific variables and the floor area, for example). This approach allows estimating differences in values of the dependent variable and influence of explanatory variables by city districts, but also has shortcomings. The main shortcoming is an artificial nature of city districts (administrative or study-specific). There no any reason why two flats located across the street but in different districts should be more different than two flats located in different parts of the same district.

In this research we overcome these disadvantages using the Geographically Weighted Regression (GWR) [4], a method based on the spatial nature of housing data.

The main practical goal of the research is to answer the question – how does the public transport accessibility influence the residential land value. The first subtask we solved here is construction of an indicator of transport accessibility. There are different ideas used in researches in this area – from a simple distance to the nearest public transport stop to complex calculations of average travel times to different locations like schools, a city business centre, other attractors [5]. We constructed our own public transport accessibility index, which is based on the distance decay function and uses as much information as possible, but remains relatively simple in calculations. This new indicator is used in the GWR to reflect the target relationship.

Within the bounds of the model we investigated the influence of other location factors like distance to supermarkets, sea/river, parks, higher educational institutes, and property characteristics like area, standard flat projects and floor numbers.

2. Theoretical Foundation

Geographically weighted regression

The traditional regression model can be written as follows:

$$y = X \cdot \beta + \varepsilon ,$$

where y is a vector of dependent variable values, X is a matrix of explanatory variables values, β is a vector of unknown coefficients and ε is a random term. Coefficients β are estimated for the global data set and shows average influences of explanatory variables.

The geographically weighted regression has a difference in coefficients [4]:

$$y = X \cdot \beta(u_i, v_i) + \varepsilon ,$$

where u_i and v_i are the coordinates of a house (a latitude and a longitude). Obviously, we need for additional information about the house location to estimate this regression, and the regression coefficients will be estimated for each flat separately. In this case we receive different estimates for each data point, which allows investigating the spatial behaviour of relationships.

For estimating the coefficients of the model for a particular flat i, we assume that flats located near to the flat i, have higher influence on the coefficients than flats located far from the flat i. In terms of regression, it means that flats located near to the point i, have larger weights. Usually the bi-square function is used for calculating a weight of the point j for the point i model:

$$w_{ij} = \begin{cases} \exp\left(-distance_{ij} \Big/ bandwidth \right), \text{for } distance_{ij} \le bandwidth, \\ 0, \text{for } distance_{ij} > bandwidth \end{cases}$$

where $distance_{ij}$ is a distance from the point i to the point j. The *bandwidth* reflects the speed of weight decreasing. There are two main approaches for the bandwidth selection – fixed and adaptive bandwidths. The fixed bandwidth is selected once for all data points, the adaptive can be changed from point to point depending on data density. The illustration of the adaptive bandwidth is presented on Figure 1.

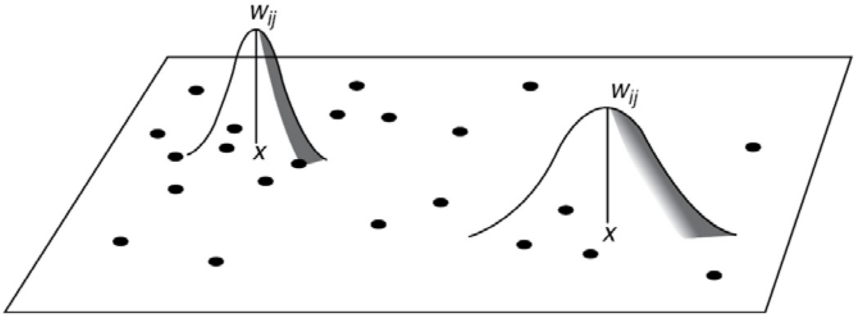

Figure 1. Geographically weighted regression with adaptive spatial bandwidths. Source: Fotheringham et al.[4]

The best bandwidth can be chosen with the Akaike Information Criterion (AIC).

In our case flats data have an inconstant density, so we used the adaptive bandwidth approach.

The coefficients are calculated for each data point using the weighted least squares method:

$$\hat{\beta}_i = \left(X^T W_i X\right)^{-1} X^T W_i Y ,$$

where W_i is a weight matrix with w_{ij} on the main diagonal and zeros on other positions.

The result of the estimation procedure is a set of estimates of coefficients for each data point.

Public transport accessibility

Measurement of public transport accessibility is thoroughly investigated in some modern studies ([6]). For our investigation we need in indicator of public transport accessibility for each flat. Obviously, the indicator should be based on the house location and distances to nearest public transport stops. If we consider a utility of a distance to the stop, we will see the classic sigma-shaped function. Some first tenth metres doesn't make a difference, after that the utility is quickly decreasing, and stabilising at a lower level again after that. We chose the log-logistic distance decay function to reflect this behaviour ([7]).

Another problem is related with taking a number of stops into account. We suggest using a sum of utilities of individual stops to aggregate all stops around the house.

So the suggested indicator can be presented by the next formula:

$$PublicTransportAccessibility_i = \sum_{route\ stop \in AREA} \frac{1}{1+\exp\left(a + b\ln\left(distance_{i,route\ stop}\right)\right)},$$

where $a = -20,\ b = 3.7$

The values of parameters a and b are chosen on the base of our fillings. The resulting distance decay function is presented on Figure 2.

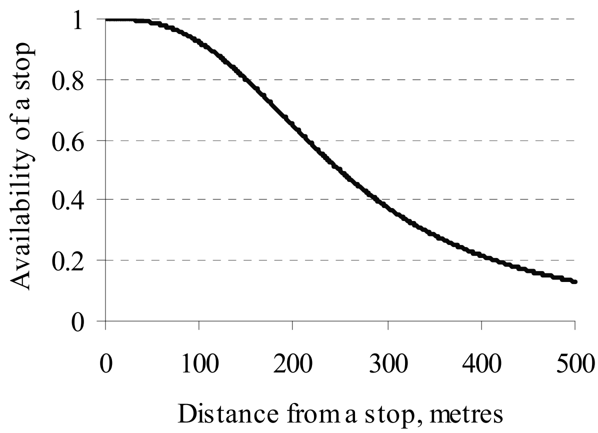

Figure 2. Distance decay function for public transport stops availability

The utility of the distance from the stop is decreasing proportionally in the interval from 100 to 400 metres; distances less than 100 and more than 400 metres don't make differences.

The sum in the formula aggregates accessibility of all route stops in the *AREA*. We use an area instead of calculations of accessibility of all transport routes, because we assume that if a stop is located significantly far from the flat it will not be used. If this research we used a circle with 1 kilometre radius to limit the *AREA*.

3. Data

We collected data about flats for sell and rent in Riga. Both samples include about 1000 flat notices dated May 2009. Also information about the public transport infrastructure, supermarkets, higher educational institutes and other attractors' location is collected.

Data has been received from the data sources below:

1. Local real estate bulletin board website (SS.lv) is used for information about flats for sell and rent. The information includes flats' characteristics – a floor area, a number of rooms, flat project plans, a floor number and a price requested. We realise that using requested prices can lead to a bias (to the higher end), but according to Hometrack [8] requested and real deal prices are highly correlated (the coefficient of correlation = 0.986) in UK and we assume the similar situation in Riga. The main goal of our research is relationship between the flat price and other characteristics, so usage of highly correlated substitute should not lead to a bias of coefficients' estimates.
   Also information about flat addresses is provided on the website. This information is translated into geographical coordinates (latitude and longitude) using the Google Earth service.
2. The information about public transport routes, stops, and schedules is received from the official site of the only public transport municipal enterprise in Riga – Rigas Satiksme.
3. The Google Local Business Centre has been used for receiving information about locations of markets, supermarkets, and railway stations.
4. A number of websites are used to supplement the Google Local Business Centre information.
5. Natural attractors (the sea side, Daugava River, green parks, including Mezaparks) are added to the Google map manually.

Distances from each flat to the nearest supermarket or market, the nearest higher educational institute are computed. Absolute distance values (without usage of a distance decay function) are used.

Also the indicator of public transport accessibility has been calculated on the base of the formula presented above. Buses, trams, trolleybuses, and railways are considered as public transport in this research.

4. Results

The first practical subtask of the research is a calculation of public transport accessibility values. The indicator has been calculated for every flat and varies from 1 to 47 points (according to the formula, each point equals to a stop just near to the flat).

Accessibility values interpolated by the Kriging procedure ([9]) are presented on Figure 3.

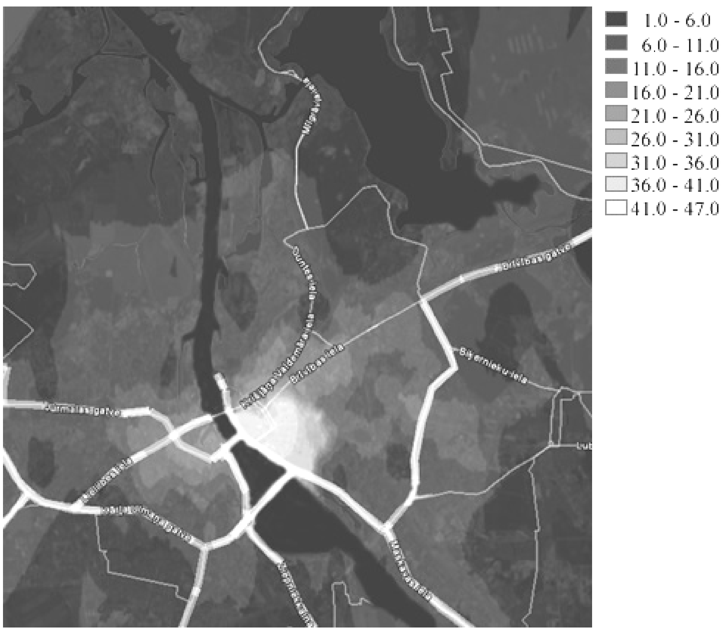

Figure 3. Accessibility of public transport in Riga

On the Figure 3 brighter areas mean higher, darker ones – lower public transport accessibility. As expected the city centre has the highest values, and outskirts have lower accessibility level.

Public transport accessibility doesn't mean its utility; habitants of the city centre have a possibility to travel to any part of the city from a stop near to the house, but they don't use all these possibilities. Habitants of outskirts usually have one-two options to travel on public transport (usually to the city centre), but they use this option very often.

Let's consider the usual global hedonic regression models for rent and sell prices (Table 1).

Table 1. Global hedonic regression models

Dependent Variable	*Rent Price*		*Sell Price*	
	Coefficient	P-value	Coefficient	P-value
FloorArea	2.8	0.000	794.6	0.000
DistanceToWater	-9.2	0.019	-4042.5	0.011
DistanceToGreen	6.1	0.376	5704.8	0.050
DistanceToSupermarket	-23.8	0.012	-5853.6	0.170
DistanceToHigherEducation	-16.1	0.000	-2265.6	0.185
PublicTransportAvailability	1.2	0.000	810.2	0.000
FirstFloor	-3.4	0.598	-3686.5	0.179
Project602	-4.1	0.649	-303.1	0.930
ProjectNew	91.1	0.000	26334.6	0.000
ProjectRenov	73.8	0.000	22310.5	0.000
Project119	-20.9	0.089	-5427.2	0.227
Constant	14.3	0.213	-15726.3	0.001

We can see significant relationships in both regressions, which can be analysed and explained.

The indicator of public transport accessibility has highly significant positive coefficients in both regressions, so we can make a conclusion about positive influence of the factor. But let's compare the influence of a new route in a city outskirt and in the city centre. We think that a new route or a new stop is much more important for the outskirt and completely unimportant for the city centre. So the average value, estimated by the global regression is correct in average, but doesn't reflect spatial features.

Another similar example is the absence of an effect of the first floor. Usually flats on the first floor are cheaper, but it also depends on the house position. We guess that the relationship, insignificant in average, can be significant for some city parts.

Also we note other coefficients that don't much alter our initial expectations (a negative relationship with distances to water, supermarkets, and higher educational institutes).

Dummy variables for flat's projects have expected values (*Project602* and *Project119* are standard flat projects popular in Riga, *ProjectNew* separates new buildings. *ProjectRenov* separates old buildings after renovation).

So we note potential problems in our global regression, possibly related with the spatial effects. One of formalised tests for spatial correlation is the Moran I coefficient ([9]). Calculated values for residuals of global hedonic sell and rent price models are presented in the Table 2.

Table 2. Moran's I values

	200 metres area		1 kilometre area	
Residuals of the global regression model for	Moran's I	p-value*	Moran's I	p-value*
Rent Price	0.066	0.000	0.036	0.000
Sell Price	0.113	0.000	0.098	0.000

* one-tail test

We have calculated Moran I values for the nearest neighbourhood (200 metres around a flat) and a mini-district (1 kilometre around the flat). In both cases for residuals of both models we receive highly significant values, which indicate the presence of spatial relationships in models' error terms. The positive sign of Moran I's attests similar residual values of flat prices in one mini-district.

On the base of previous reasoning and Moran I's values we have decided to use the geographically weighted regression. In this paper we present the most interesting moments of the resulting regression only.

The first practical question for the regression is a relationship between prices and public transport accessibility. According to the GWR approach coefficients are calculated for every data point. The most interesting things for us are significance and direction of the relationship. Both characteristics can be presented by coefficient's t (Student) value. The interpolations of t-values (for the rent price model) are presented on Figure 4.

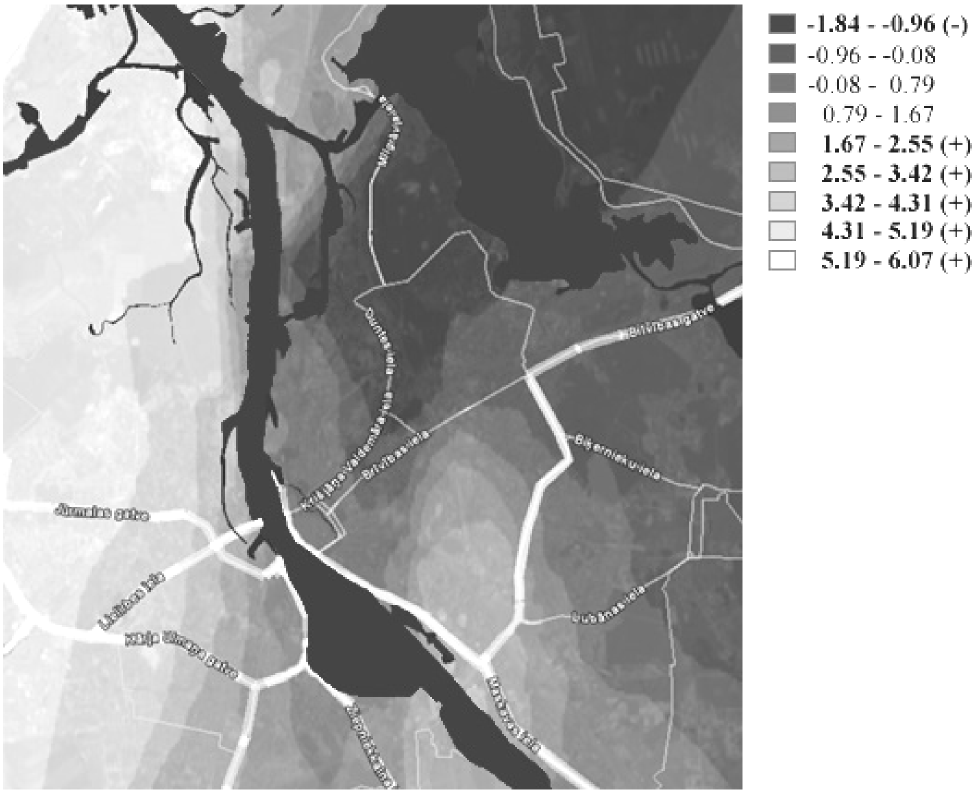

Figure 4. The relationship between public transport accessibility and flat rent prices (t-values)

Darker areas reflect negative relationship, brighter areas – positive relationship (significant areas are marked in the legend with "–" and "+" signs accordingly).

We can note that the most outskirts have an expected positive relationship, which indicates that every new transport route and stop will increase flat prices. The areas with a significant positive relationship cover a sizeable share of the map, which leads to a significantly positive average value (in the global regression).

As we expected the city centre doesn't have a significant relationship between flat prices and transport accessibility. The city centre is rich with transport routes and new routes will not affect flat prices.

There are areas with a significant (or near to be significant) negative relationship. The areas cover Mezaparks and adjacent regions, which is a place with good ecological environment and beautiful nature located not far from the city centre, and, therefore, a place of settlement of people with higher income level. This factor leads to higher level of private car usage by habitants and higher utility of peace of quiet, hardly compatible with intensive public transport movements. Surprisingly, the negative relation is near to be significant in the Sarkandaugava district, which additionally can be explained by roads with intensive transport movements used by public transport. The nearness of thoroughfare, not included into the models directly, can overpower positive effects of the public transport.

We can compare global regression and geographically weighted regression models using the Akaike information criterion, AIC (Table 3).

Table 3. Model comparison on the bas of Akaike Information Criterion

	Global regression	Geographically Weighted regression
Rent Price	9994	9893
Sell Price	13576	13465

Smaller values of AIC indicate better models; a difference in more than about 3 point is a significant one. As we can see the GWR regressions are significantly better in both cases.

Relationships between a flat price and other explanatory variables also have spatial effects. For example, the influence of the first floor on the price is insignificant in the global regression model, but using the GWR we have discovered local dependencies. In the sell price model the first floor is highly significant in the city centre (and in the Pardaugava district situated on the opposite river side) and has a negative effect. For all other city regions the influence of the first floor on the price is insignificant.

5. Conclusions

In this research we have constructed the indicator of public transport accessibility and estimated its relationship with the residential land value (in forms of flat rent and sell prices).

The public transport accessibility indicator is constructed on the base of information about spatial positions of houses, and stop and routes of public transport. The calculated values have an expected distribution – the city centre has higher values of public transport accessibility and city outskirts have lower values. The suggested indicator can be used for further research of the transport infrastructure.

Analytical reasoning and formalised tests lead to a conclusion about unsatisfactory results of the usual global hedonic regression model. We have used a relatively new method – the geographically weighted regression – to reflect spatial effects in the data. Estimating the GWR parameters we note significant differences in influence of public transport accessibility on flat prices. We ascertained city areas with positive and negative relationships, and also the city centre with absence of the significant relationship.

We have investigated influence of other flat characteristic like floor area, floor number, distances to supermarkets, higher educational institutes and natural attractors, and also discovered spatial features.

The results of the research can be used in composing of public transport infrastructure chapter of the city development plan.

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Transport and Telecommunication, 2009, Volume 10, No 2, 33–42
Transport and Telecommunication Institute, Lomonosova 1, Riga, LV-1019, Latvia

RELIABILITY AND FUNCTIONAL ANALYSIS OF DISCRETE TRANSPORT SYSTEMS BY MODELLING AND SIMULATION

Tomasz Walkowiak, Jacek Mazurkiewicz

Institute of Computer Engineering, Control and Robotics
Wroclaw University of Technology
ul. Janiszewskiego 11/17, 50-372 Wroclaw, Poland
E-mails: Tomasz.Walkowiak@pwr.wroc.pl, Jacek.Mazurkiewicz@pwr.wroc.pl

The paper describes a novel approach to the analysis of discrete transport systems (DTS). The proposed method is based on modelling and simulating of the system behaviour. Monte Carlo simulation is a tool for DTS performance metric calculation. No restriction on the system structure and on a kind of distribution is the main advantage of the method. The system is described by the formal model, which includes reliability and functional parameters of DTS. The paper presents a description of developed simulator with its performance analysis. Moreover a case study based on real transport system with exemplar results is given.

Keywords: reliability, discrete transport system, Monte-Carlo simulation

1. Introduction

Administration of a large transport system is not a trivial task. The transport systems are characterized by a very complex structure. The performance of the system can be impaired by various types of faults related to the transport vehicles, communication infrastructure or even by traffic congestion [1]. It is hard for human (administrator, owner) to understand the behaviour of the system. To overcome this problem we propose a functional approach. The transport system is analysed from the functional point of view, focusing on business service realized by a system [2]. The analysis is following a classical [3]: modelling and simulation approach. It allows calculating different system measures, which could be a base for decisions related to administration of the transport systems. The metric are calculated using Monte Carlo techniques [4]. No restriction on the system structure and on a kind of distribution is the main advantage of the method. The proposed model allows forgetting about the classical reliability analysis based on Markov or Semi-Markov processes [5] – idealized and hard for reconciliation with practice.

The paper presents an analysis of transport system of the Polish Post regional centre of mail distribution (described in section 2). Base on which we have developed the discrete transport system model presented in section 3. The delivery of mails is the main service given by the post system. From the client's point of view the quality of the system could be measured by the time of transporting the mail from the source to destination. Therefore, the quality of the analysed system is measured by the availability defined as an ability to realize the transportation task at a required time (described in section 4).

The post system is very hard to be analysed by a formal model since it does not lie in the Markov process framework. Therefore, we have used a computer simulation [3] described in section 5. Next (section 6), we give an example of using presented model and simulator for the analysis of the Polish Post regional centre in Wroclaw transport system and discussed the performance of developed simulator.

2. Transport System of Polish Post

The analysed transport system is a simplified case of the Polish Post. The business service provided the Polish Post is the delivery of mails. The system consists of a set of nodes placed in different geographical locations. Two kinds of nodes could be distinguished: central nodes (CN) and ordinary nodes (ON). There are bidirectional routes between nodes. Mails are distributed among ordinary nodes by trucks, whereas between central nodes by trucks, railway or by plain. The mail distribution could be understood by tracing the delivery of some mail from point A to point B. At first the mail is transported to the nearest to A ordinary node. Different mails are collected in ordinary nodes, packed in larger units called containers and then transported by trucks scheduled according to some time-table to the nearest central node. In central node containers are repacked and delivered to appropriate (according to delivery address of each mail) central node. In the Polish Post there are 14 central nodes and more than 300 ordinary nodes. There are more than one million mails going through one central node within 24 hours. It gives a very large system to be modelled and simulated. Therefore, we have decided to model only a part of the Polish Post transport system – one central node with a set of ordinary nodes.

Essential in any system modelling and simulation is to define the level of details of modelled system. Increasing the details causes the simulation becoming useless due to the computational complexity and a large number of required parameter values to be given. On the other hand a high level of modelling could not allow recording required data for system measure calculation. Therefore, the crucial think in the definition of the system level details is to know what kind of measures will be calculated by the simulator. Since the business service given by the post system is the delivery of mails on time. Therefore, we have to calculate the time of transporting mails by the system. Since the number of mails presented in the modelled system is very large and all mails are transported in larger amounts containers, we have decided to use containers as the smallest observable element of the system. Therefore, the main observable value calculated by the simulator will be the time of container transporting from the source to the destination node.

The income of mails to the system, or rather containers of mails as it was discussed above, is modelled by a stochastic process. Each container has a source and destination address. The central node is the destination address for all containers generated in the ordinary nodes. Where containers addressed to any ordinary nodes are generated in the central node. The generation of containers is described by some random process. In case of central node, there are separate processes for each ordinary node. Whereas, for ordinary nodes there is one process, since commodities are transported from ordinary nodes to the central node or in the opposite direction.

The containers are transported by vehicles. Each vehicle has given capacity – maximum number of containers it can haul. Central node is a base place for all vehicles. They start from the central node and the central node is the destination of their travel. The vehicle hauling a commodity is always fully loaded or taking the last part of the commodity if it is less than its capacity. Vehicles operate according to the time-table. The time-table consists of a set of routes (sequence of nodes starting and ending in the central node, times of leaving each node in the route and the recommended size of a vehicle). The number of used vehicle and the capacity of vehicles do not depend on temporary situation described by number of transportation tasks or by the task amount for example. It means that it is possible to realize the route by completely empty vehicle or the vehicle cannot load the available amount of commodity (the vehicle is to small). Time-table is a fixed element of the system in observable time horizon, but it is possible to use different time-tables for different seasons or months of the year.

Summarizing the movement of the containers in the system, a container is generated with destination address in some of node (source) at some random time. Next, the container waits in the node for a vehicle to be transported to the destination node. Each day a given time-table is realized, it means that at a time given by the time-table a vehicle, selected from vehicles available in the central node, starts from central node and is loaded with containers addressed to each ordinary nodes included in a given route. This is done in a proportional way. When a vehicle approaches the ordinary node it is waiting in an input queue if there is any other vehicle being loaded/unload at the same time. There is only one handling point in each ordinary node. The time of loading/unloading vehicle is described by a random distribution. The containers addressed to given node are unloaded and empty space in the vehicle is filled by containers addressed to a central node. Next, the vehicle waits till the time of leaving the node (set in the time-table) is left and starts its journey to the next node. The operation is repeated in each node on the route and finally the vehicle is approaching the central node when it is fully unloaded and after it is available for the next route. The process of vehicle operation could be stopped at any moment due to a failure (described by a random process). After the failure, the vehicle waits for a maintenance crew (if there are no available due to repairing other vehicles), is being repaired (random time) and after it continues its journey. The vehicle hauling a commodity is always fully loaded or taking the last part of the commodity if it is less than its capacity.

3. Formal Model of the Discrete Transport System

3.1. Model overview

The described in the previous section regional part of the transport system of Polish Post with one central node and several ordinary nodes was a base for a definition of a formal model of a discrete transport system (DTS).

Generally speaking users of the transport system are generating tasks, which are being realized by the system. The task to be realized requires some services presented in the system. A realization of the system service needs a defined set of technical resources. Moreover, the operating of vehicles transporting mails between system nodes is done according to some rules – some management system. Therefore, we can model discrete transport system as a 4-tuple:

$$DTS = \langle Client, BS, TI, MS \rangle \tag{1}$$

$Client$ – client's model,
BS – business service, a finite set of service components,
TI – technical infrastructure,
MS – management system.

3.2. Technical infrastructure

During modelling of technical infrastructure we have to take into consideration functional and reliability aspects of the post transport system. Therefore, the technical infrastructure of DTS could be described by three elements:

$$TI = \langle No, V, MM \rangle, \tag{2}$$

where: *No* – set of nodes; *V* – set of vehicles; *MM* – maintenance model.

Set of nodes (*No*) consists of single central node (*CN*), a given number of ordinary nodes (ON_i). The distance between each two nodes is defined by the function:

$$distance : No \times No \to R_+ . \tag{3}$$

Each node has one functional parameter the mean (modelled by normal distribution) time of loading a vehicle:

$$loading : No \to R_+ . \tag{4}$$

Moreover, the central node (*CN*) has additional functional parameter: number of service points (in each ordinary node there is only one service point):

$$servicepoints : CN \to N_+ . \tag{5}$$

Each vehicle is described by the following functional and reliability parameters:

- mean speed of a journey

  $$meanspeed : V \to R_+ , \tag{6}$$

- capacity – number of containers which can be loaded

  $$capacity : V \to R_+ , \tag{7}$$

- mean time to failure

  $$MTTF : V \to R_+ , \tag{8}$$

  time when failure occurs is given by exponential distribution with mean equal to a value of *MTTF* function,
- mean repair time

  $$MRT : V \to R_+ . \tag{9}$$

The traffic is modelled by a random value of vehicle speed and therefore the time of vehicle (*v*) going from one node (n_1) to the other (n_2) is given by a formula:

$$time(v,n_1,n_2) = \frac{distance(n_1,n_2)}{Normal(meanspeed(v), 0.1 \cdot meanspeed(v))}, \tag{10}$$

where *Normal* denotes a random value with the Gaussian distribution.

Maintains model (*MM)* consists of a set of maintenance crews which are identical and unrecognised. The crews are not combined to any node, are not combined to any route, they operate in the whole system and are described only by the number of them. The time when a vehicle is repaired is equal to the time of waiting for a free maintains crew (if all crews involved into maintenance procedures) and the time of a vehicle repair which is a random value with the Gaussian distribution ($Normal(MRT(v), 0.1 \cdot MRT(v))$.

3.3. Business service

Business service (*BS*) is a set of services based on business logic that can be loaded and repeatedly used for concrete business handling process. Business service can be seen as a set of service components and tasks that are used to provide service in accordance with business logic for this process. Therefore, *BS* is modelled a set of business service components (*sc*),):

$$BS = \{sc_1, ..., sc_n\}, n = length(BS) > 0, \tag{11}$$

the function *length*(*X*) denotes the size of any set or any sequence *X.*

Each service component in DTS consist of a task of delivering a container from a source node to the destination one.

3.4. Client's model

The service realised by the clients of the transport system are sending mails from a source node to a destination one. Client's model consists of a set of clients (*C*).

Each client is allocated in one of nodes of the transport system:

$$allocation: C \to No. \tag{12}$$

A client allocated in an ordinary node is generating containers (since, we have decided to monitor containers not separate mails during simulation) according to the Poisson process with destination address set to ordinary nodes. In the central node, there is a set of clients, one for each ordinary node. Each client generates containers by a separate Poisson process and is described by intensity of container generation:

$$intensity: C \to R_+. \tag{13}$$

The central node is the destination address for all containers generated in ordinary nodes.

3.5. Management system

The management system (*MS*) of the DTS controls the operation of vehicle. It consists of a sequence of routes:

$$MS = \langle r_1, r_2, ..., r_{nr} \rangle. \tag{14}$$

Each route is a sequence of nodes starting and ending in the central node, times of leaving each node in the route (t_i) and the recommended size of a vehicle (*size*) :

$$r = \langle CN, t_0, n_1, t_1, ..., n_m, t_m, CN, size \rangle \quad v_i \in No - \{CN\} \quad 0 \le t_0 < t_1 < ... < t_m < 24h$$

The routes are defined for one day (so, all times are values less than 24 h of leaving the node) and are repeated each day.

The management system selects vehicles to realise each route in random way, first of all vehicles (among vehicles available in central node) with capacity equal to recommended size are taken into consideration. If there is no such vehicle, vehicles with larger capacity are taken into consideration. If still there is no vehicle fulfilling requirements vehicle from vehicles with smaller size is randomly selected. If there is no available vehicle a given route is not realized.

4. Functional Metrics of DTS

4.1. Metrics overview

The formal model described above was designed to allow developing a simulator (described in the next section) which allows observing the time of transporting each container. Based on these observations several metrics could be defined.

As it was mentioned in the introduction we focus here on the service oriented approach [2]. Therefore we propose that the availability will be a key parameter for the evaluation of the quality of the DTS.

One can define the availability in different ways, but always the value of availability can be easy transformed into economic or functional parameters perfectly understood by owner of the system.

The availability is mostly understood as a probability that a system is up; and is defined as a ratio of the expected value of the uptime of a system to the observation time. It is a simple definition but requires defining what does it mean that transport system is working. The similar metric is the acceptance ratio defined in information since as a number of accepted requests to the total number of requests.

4.2. Functional availability

In paper [6] we have proposed the definition of up time as a time when the number of delayed containers does not exceed a given threshold. Let introduce the following notation:

- T – a time measured from the moment when the container was introduced to the system to the moment when the container was transferred to the destination (random value),
- T_g – a guaranteed time of delivery, if exceeded the container is delayed.
- $N_{deleyed}(t)$ – a stochastic process describing the number of delayed containers at time t, i.e. the number of containers for which T> T_g .

Therefore, the functional availability $A_k(t)$ can be defined as a probability that the number of delayed containers at time t does not exceed k, the value k is the level of acceptable delay:

$$FA_k(t) = \Pr\{N_{deleyed}(t) \le k\}. \tag{15}$$

4.3. Average functional availability

The defined in the previous section functional availability describes a state of an analysed system at a given point of time. In case if somebody wants to analyse a state of system in a time interval we have proposed in [7] the other metric: average functional availability $AFA_k(t)$. It is defined as an average probability that a system in the time interval from 0 to t is in up-time state (i.e. the number of delayed containers does not exceed threshold k):

$$AFA_k(t) = \frac{1}{t}\int_0^t \Pr\{N_{deleyed}(\tau) \le k\} d\tau . \tag{16}$$

4.4. Acceptance ratio

In [8] we have proposed other performance metric – acceptance ratio. It is defined as a ratio of on-time containers (containers for which T< T_g) to all containers within a given time period (24h was used). Therefore a sequence of time moments ($\tau_0, \tau_2, ..., \tau_i, ..., \tau_n$) when the metric is calculated has to be set – a midnight of each day was used (i.e. $\tau_i - \tau_{i-1} = 24h$). Within each time period (τ_{i-1}, τ_i), a given number of containers are delivered ($N_{delivered}(\tau_{i-1}, \tau_i)$), a part of if or all delivered on time ($N_{ontime}(\tau_{i-1}, \tau_i)$), but at the end of analysed period time there could be some containers not yet delivered (waiting in the source node or being transported) $N_{insystem}(\tau_i)$ and all or part of them being not late yet ($N_{ontimeinsystem}(\tau_i)$). Taking into consideration introduced symbols the availability could be calculated as the expected value (Monte-Carlo approach) of ratio of on-time containers to all containers:

$$AR\ (t_i) = E\left(\frac{N_{ontime}(\tau_{i-1}, \tau_i) + N_{ontimeinsystem}(\tau_i)}{N_{delivered}(\tau_{i-1}, \tau_i) + N_{insystem}(\tau_i)} \right). \tag{17}$$

5. Discrete Transport System Simulation

5.1. Event-driven simulation

Discrete transport system described in the previous section is very hard to be analysed by formal methods. It does not lie in the Markov process framework [5]. A common way of analysing that kind of systems is a computer simulation. To analyse the system we must first build a simulation model, which was done based on the formal model presented in the previous section, and then operate the model. The system model needed for simulation has to encourage the system elements behaviour and interaction between elements.

Once a model has been developed, it is executed on a computer. It is done by a computer program, which steps through time. One way of doing it is the so-called event-driven simulation. It is based on an idea of event, which could be described by time of event occurring and type of an event. The simulation is done by analysing a queue of event (sorted by time of event occurring) while updating the states of system elements according to rules related to a proper type of event. Due to a presence of randomness in the DTS model the analysis of it has to be done based on Monte-Carlo approach [4]. It requires a large number of repeated simulations.

Summarizing, the event-driven simulator repeats *N*-times the following loop:

- beginning state of a DTS initialisation,
- event state initialisation, set time $t = 0$,
- repeat until $t < T$:
- take first event from event list,
- set time equals time of event,
- realize the event – change state of the DTS according to rules related to proper type of event: change objects attributes describing system state, generate new events and put them into event list, write data into output file.

5.2. Events and elements of DTS simulator

In case of DTS following events (mainly connected with vehicles) have been defined:

- vehicle failure,
- vehicle starts repair,
- vehicle repaired,
- vehicle reached the node,
- vehicle starts from the node,
- vehicle is ready for the next route,
- time-table (starting the route in the central node).

The processing of events done in objects is representing DTS elements. The objects are working in parallel. The following types of system elements are distinguished: vehicle, ordinary node, central node, time-table.

The life-cycle of each object consists of waiting for an event directed to this object and then execution of tasks required to perform the event. These tasks includes the changes of internal state of the object (for example when vehicle approaches the node it is unloaded, i.e. the number of hauled containers decreases) and sometimes creating a new even (for example the event vehicle starts from the node generates new event vehicle reached the node – next node in the trip). The random number generator is used to deal with random events, i.e. failures. It is worth to notice that the current analysed event not only generates a new event but also could change time of some future events (i.e. time of approaching the node is changed when failure happens before). The time of a new event is defined by the sum of current time (moment of execution of the current event) and the duration of a given task (for example, vehicle repair). Only times of starting a given route (event vehicle starts from the central node) are predefined (according to the time-table). Duration of all other tasks are defined by system elements states:

- time when vehicle waits in the queue for loading/unloading,
- time when vehicle waits in the queue for maintains crew,
- or are given by random processes:
- time of vehicle going between two nodes,
- time of loading/unloading,
- time to failure,
- repair time.

Moreover each object representing a node have additional process (working in parallel) which are responsible for generating containers. The life cycle of this process is very simple: waiting a random time, generating a container with a given destination address (central node for all ordinary nodes, and each ordinary nodes for process in the central node) and storing a container in the store house (implemented as a queue) of a given node.

5.3. DTS simulator implementation

The event-simulation program could be written in a general purpose programming language (like C++), in a fast prototyping environment (like Matlab) or a special purpose discrete-event simulation kernel. One of such kernels, is the Scalable Simulation Framework (SSF) [9] which is a used for SSFNet [9,10] computer network simulator. SSF is an object-oriented API - a collection of class interfaces with prototype implementations. It is available in C++ and Java. SSFAPI defines just five base classes: Entity, inChannel, outChannel, Process, and Event. The communication between entities and delivery of events is done by channels (channel mappings connects entities).

For the purpose of simulating DTS we have used Parallel Real-time Immersive Modelling Environment (PRIME) [10] implementation of SSF due to a much better documentation then available for the original SSF. We have developed a generic class derived from SSF Entity which is a base of classes modelling

DTS objects which models the behaviour of presented in section 2 and 3 discrete transport system.

As it was mentioned a presence of randomness in the DTS model, the Monte-Carlo approach is used. The original SSF was not designed for this purpose so some changes in SSF core were done to allow to restart the simulation from time zero several times within one run of simulation programme.

The statistical analysis of the system behaviour requires a very large number of simulation repetition, therefore the time performance of developed simulator is very important.

6. Analysis Results of DTS Simulation

6.1. Exemplar DTS

We propose for the case study analysis an exemplar DTS based on Polish Post regional centre in Wroclaw. We have modelled a system consisting of one central node (Wroclaw regional centre) and twenty two other nodes - cities where there are local post distribution points in Dolny Slask Province. The length of roads was a set according to real road distances between cities used in the analysed case study. The intensity of generation of containers for all destinations was a set to 4.16 per hour in each direction giving in average 4400 containers to be transported each day. The vehicles speed was modelled by Gaussian distribution with 50 km/h of mean value and 5 km/h of standard deviation. The average loading time was equal to 5 minutes. There were two types of vehicles: with capacity of 10 and 15 containers. The MTF of each vehicle was set to 2000. The average repair time was set to 5h (Gaussian distribution). The time-table consists of 184 routes. [8]

6.2. Availability metric

The simulation time was set to 100 days and each simulation was repeated 10.000 times. We have calculated functional metrics defined in section 4. The achieved results, functional availability and average one for guaranteed delay 24 and acceptable delay 10 containers, are presented on Figure 1. The functional availability is dropping down each 24 hours due to a definition of time-table, vehicles are not working at night, but containers are entering the system all the time.

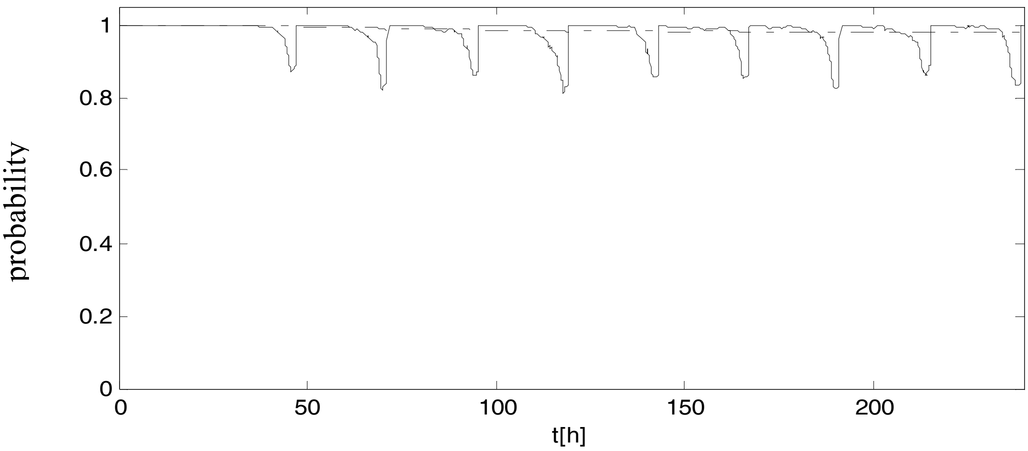
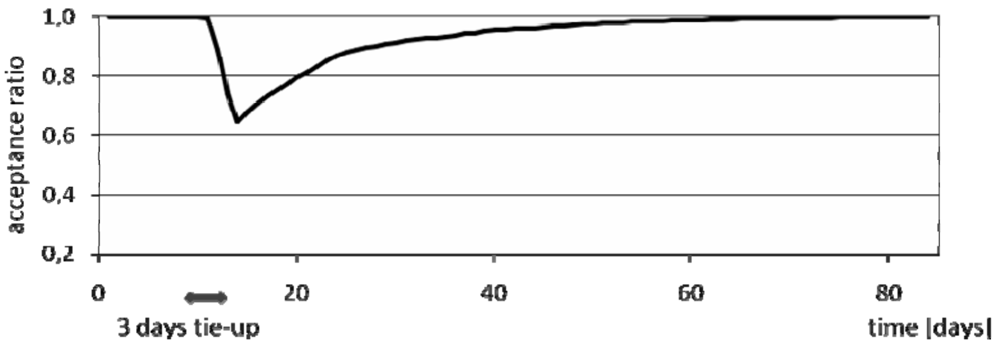


Figure 1. Availability (solid line) and average availability (dashed-dot line) for the exemplar DTS

6.3. Critical situation

The developed simulation allows analysing the transport system performance in case of some critical situations. Let assume that for some days the system is not working at all. The tie-up of the system could be caused for example by a driver strike. After a given number of days the system is again working. The achieved results (acceptance ratio calculated according to (17)) for 3 and 10 days tie-up are presented on Figure 2a and 2. As it could be expected the acceptance ratio in day 6 (when tie-up starts) is starting to drop down and when drivers come back is slowly enlarging. The Figure 3 presents how many days are needed for the transport system to achieve a required level (0.9, 0.95 and 0.98) after a tie-up of the different length.

a)



b)

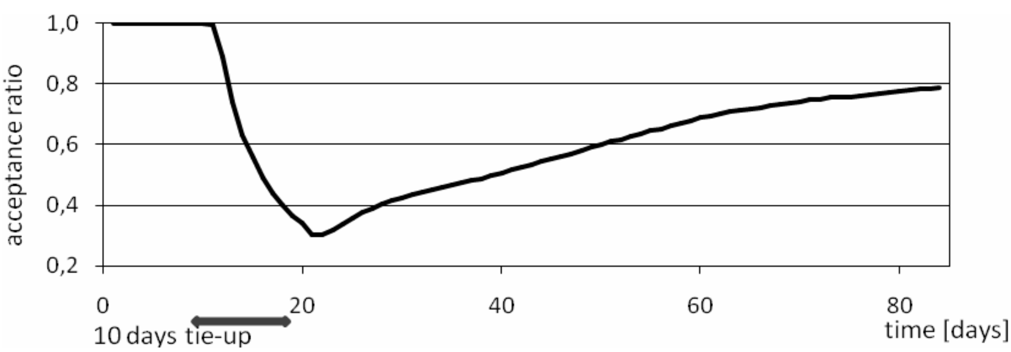


Figure 2. Acceptance ratio for a 3 days (a) and 10 days (b) tie-up

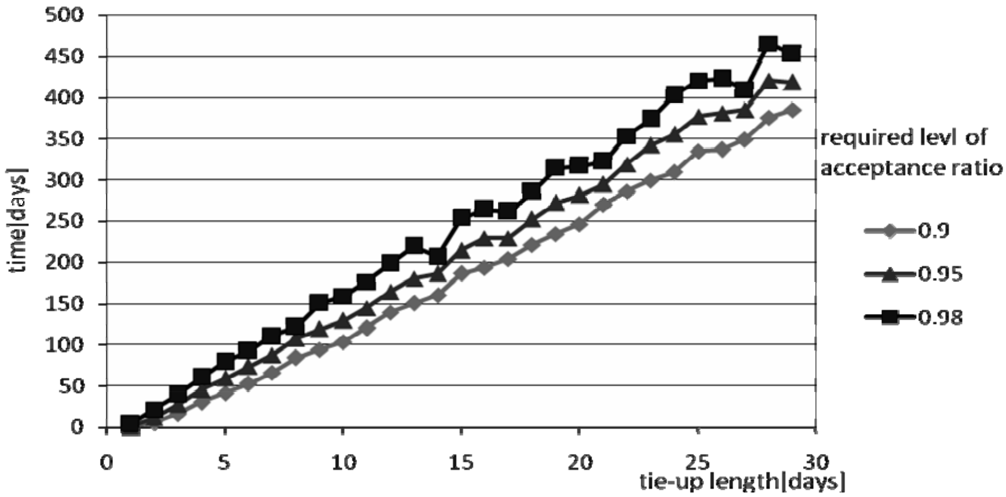


Figure 3. The time required to achieve a given level of acceptance ratio after a tie-up of different length for the exemplar DTS

6.4. DTS simulator performance

Next, we have tested the DTS simulator performance and scalability. We calculated the time of running one batch of simulation of the exemplar DTS presented above for 100 days on a 2.80 GHz Intel Core Duo machine on Linux system (Table 1). The CYGWIN base Windows implementation of PRIME SSF was around 10 times slower then Linux one. Next, we have enlarged the number of containers transported each day 10, 50, 100 and 500 times and proportionally enlarged the transport system (number of trucks, routes and service points). As it could be seen in Table 1 and Figure 4 the memory usage is linearly proportional to a number of containers transported each day, whereas the simulation time is polynomial proportional.

We think that the time and memory effectiveness of simulation done in PRIME environment is very promising. Of course the time needed to perform one simulation depends on the number of events presented in the system, which is a result DTS configuration.

Table 1. DTS simulator performance

	Reference DTS	10 x larger	50 x larger	100 x larger	500 x larger
Number of trucks	52	520	2 600	5 200	26 000
Number of router per day	184	1 840	9 200	18 400	92 000
Number of containers per day	4 400	44 000	220 000	440 000	2 200 000
Simulation time	0.21s	2.60 s	31.91 s	154.5 s	1910.0 s
Memory usage	2 MB	12 MB	63 MB	125 MB	600 MB

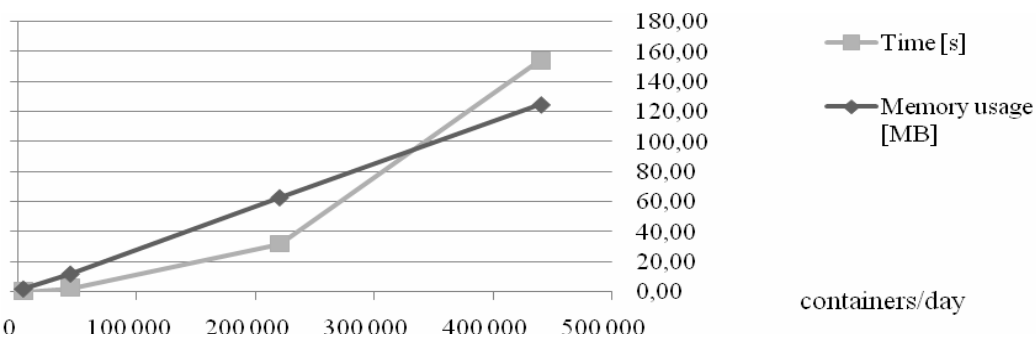


Figure 4. Simulator simulation time and memory usage in a function of number of containers per day generated in DTS

7. Conclusions

We have presented a formal model and event-driven simulator of discrete transport system (DTS). The DTS model is based on Polish Post regional transport system. Simulator was implemented using the Scalable Simulation Framework (SSF). The simulator allows performing reliability and functional analysis of the DTS, for example:

- determine what will cause a ”local” change in the system,
- make experiments in case of increasing number of containers per day incoming to system,
- identify weak point of the system by comparing few its configuration,
- better understand how the system behaves.

Based on the results of simulation it is possible to create different metrics to analyse the system in case of reliability, functional and economic case. The availability, average availability and acceptance ratio of the system was introduced – defined in a functional way by delayed tasks realization. The metric could be analysed as a function of different essential functional and reliability parameters of DTS. Also the system could be analysed in case of some critical situation (like, for example, a few day tie-up). The paper includes some exemplar systems, based on real Polish Post Wroclaw area, and calculated metric.

The achieved performance of the DTS simulator makes it a practical tool for defining an organization of vehicle maintenance and transport system logistics.

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Transport and Telecommunication, 2009, Volume 10, No 2
Transport and Telecommunication Institute, Lomonosov 1, Riga, LV-1019, Latvia

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CUMULATIVE INDEX

TRANSPORT and TELECOMMUNICATION, Volume 10, No 2, 2009 *(Abstracts)*

Bazaras, D., Palšaitis, R. Estimation of Logistics Situation Changes 2007-2009 in Lithuania. *Transport and Telecommunication*, Vol. 10, No 2, 2009, pp. 4–9.

Surveys of logistics situation in Lithuania have been performed in Vilnius Gediminas Technical University in 2007. This survey discovered mostly relevant problems in logistics: costs policy, logistics competences, and personnel competence development requirements. During this investigation the positive trends of logistics IT systems development have been identified. The product customisation, inventory management, warehousing, invoicing, order processing and reverse logistics outsourcing are relevant. The majority of Logistics companies supposed that their operating environment in Lithuania is good enough. Surveys results indicate that Lithuanian logistics companies have positive tendencies in the self assessment from the different point of view. In this article the main results of this survey are presented. In light of economical crisis of the end of 2008 the main survey results are revised and new surveys' directions for future investigations are formed.

Keywords: logistics, transport policy, survey

Kabashkin, I., Lotter, H.-J. Common Virtual Environment in the European Transport Training. *Transport and Telecommunication*, Vol. 10, No 2, 2009, pp. 10–15.

The creation of a united European transport market without restrictions or barriers to access, based on harmonised conditions of competition, is becoming one of the principal objectives of common transport policy in Europe.

In the same way as transport systems, processes and services operate in an increasingly more European framework, transport education and training need to change their contents taking international aspects and globalisation into consideration and move from conventional to networked environments. Even initial transport education processes at vocational and higher educational levels must be a part of these dynamic changes to enable their graduates to meet employers' needs and perform at the market.

The establishment of Innovative Virtual European Transport Training Agency (IVETTA) is one of the steps toward this direction.

The IVETTA is an educational network of persons and institutions involved in transport education and training and interested in supporting it by use of multimedia and information technologies. It focuses on enabling transport educators and trainers to introduce any kinds of educational multimedia, new technologies and common standards to their educational processes as knowledgeable consumers or well acquainted supervisors or even to become enthusiastic multimedia developers. For this, there is required not only an appropriate technological infrastructure but also an organizational basis and culture encouraging collaboration and exchange to the benefit of all of the network's members.

The mission of IVETTA is creation of standards for the development and adoption of technologies that enable high-quality, accessible, and affordable transport education and training experiences. IVETTA will be enabling the next generation of Digital Learning Services, combining new forms of digital content, assessment, applications, and administrative services.

Strategic goal of IVETTA is increasing quality and safety of all mode of transport on the base of high quality standards in the life-long education and training and common network of training, industry and maintenance organizations.

Paper describes main objectives, innovation strategy focuses, main activities of future network co-operation and results, expected to be worked out by the IVETTA.

Keywords: transport, training, education

Paramonov, Yu., Kuznetsov, A. Reliability of Fatigue-Prone Airframe. Inspection Program Control. *Transport and Telecommunication*, Vol. 10, No 2, 2009, pp. 16–25.

Algorithm of inspection program development and control using theory of Markov chains and p-set function definition on the base of processing of approval lifetime test result is discussed.We make assumption that some Structural Significant Item (SSI), the failure of which is the failure of the whole system, is characterized by a random vector (r.v.) (T_d, T_c), where T_c is critical lifetime (up to failure), T_d is service time, when some damage (fatigue crack) can be detected. We suppose also that a required operational life of the system is limited by the so-called Specified Life (SL), $\boldsymbol{t}_{SL}$, when system is discarded from service. Some examples are given.

Keywords: inspection program, Markov chains, reliability

Pavlyuk, D. Statistical Analysis of the Relationship between Public Transport Accessibility and Flat Prices in Riga. *Transport and Telecommunication*, Vol. 10, No 2, 2009, pp. 26–32.

The relationship between public transport accessibility and residential land value is a point of interest of many recent researches. A hedonic price regression model, widely used in this research area, has one very important shortcoming – it calculates an "average" influence of factors on land value in the analysing area. Usually spatial effects present in data, and the influence of public transport accessibility can be distributed over the area non-uniformly.

In this study we apply a comparatively new modification of the regression model – geographically weighted regression – to examine the relationship between public transport accessibility and residential land value (in a form of rent and sell prices) in Riga. The proposed method allows taking into account spatial effects present in the relationship.

We use information about geographical locations of urban public transport stops and routes to calculate a level of transport accessibility.

Together with the transport accessibility level and a common set of property-specific parameters (floor area, number of rooms, etc.) we consider additional hedonic properties of a flat location such as distances to supermarkets, higher schools and natural attractors like large parks, the river, and the seaside.

Keywords: geographically weighted regression, hedonic price model, public transport accessibility

Walkowiak, T., Mazurkiewicz, J. RELIABILITY AND FUNCTIONAL ANALYSIS OF DISCRETE TRANSPORT SYSTEMS BY MODELLING AND SIMULATION. *Transport and Telecommunication*, Vol. 10, No 2, 2009, pp. 33–42.

The paper describes a novel approach to the analysis of discrete transport systems (DTS). The proposed method is based on modelling and simulating of the system behaviour. Monte Carlo simulation is a tool for DTS performance metric calculation. No restriction on the system structure and on a kind of distribution is the main advantage of the method. The system is described by the formal model, which includes reliability and functional parameters of DTS. The paper presents a description of developed simulator with its performance analysis. Moreover a case study based on real transport system with exemplar results is given.

Keywords: reliability, discrete transport system, Monte-Carlo simulation

TRANSPORT and TELECOMMUNICATION, 10.sējums, Nr.2, 2009 (Anotācijas)

Bazaras, D., Palšaitis, R. Loģistikas situācijas izmaiņas Lietuvā 2007.-2009. gadā un to novērtējums**.** *TRANSPORT and TELECOMMUNICATION,* 10.sēj., Nr.2, 2009, 4.–9. lpp.

Pārskats par loģistikas situāciju Lietuvā tika izstrādāts Viļņas Tehniskajā Universitātē 2007. gadā. Šajā pārskatā tika atklātas lielākoties būtiskas problēmas loģistikā: izmaksu politika, loģistikas kompetences, personāla kompetenču attīstības prasības. Šī pētījuma laikā tika atklāti pozitīvi virzieni loģistikas IT sistēmu attīstībā. Produktu muitošana, inventarizācijas pārvaldība, noliktavu darbība, pavadzīmju kārtošana, pasūtījumu darbība un pretēja loģistikas darba decentralizācija – viss minētais ir būtisks. Lietuvas loģistikas kompāniju lielākais vairums ir pārliecināti, ka viņu darbība ir apmierinoša. Pēc pētījuma rezultātiem var konstatēt, ka Lietuvas loģistikas kompānijām ir pozitīvas tendences pašnovērtēšanā no dažādiem aspektiem. Rakstā autori analizē galvenos 2008. gada pārskata rezultātus ekonomiskās krīzes ietekmē, kā arī tiek doti jauni virzieni pētījumiem nākotnē.

Atslēgvārdi: loģistika, transportēšanas politika, pārskats

Kabaškins, I., Loters, H.-J. Kopēja virtuālā vide Eiropas transporta apmācībā. *TRANSPORT and TELECOMMUNICATION,* 10.sēj., Nr.2, 2009, 10.–15. lpp.

Vienota Eiropas transporta tirgus radīšana bez dažādiem ierobežojumiem un barjerām, lai tuvinātos, bāzēta uz konkurences saskaņotiem apstākļiem, kļūst par vienu no principiāliem mērķiem kopējā Eiropas transporta politikā. Tāpat kā transporta sistēmas, procesi un pakalpojumi darbojas lielākajā Eiropas daļā, transportapmācībai un izglītošanai ir nepieciešams mainīt tā saturu, ņemot vērā starptautiskos aspektus un globalizāciju, un jāvirzās no vispārpieņemtas uz tīkla vidi. Šajā sakarā kā viens no soļiem minētajā virzienā tika izveidota Inovatīvā virtuālā Eiropas transporta apmācības aģentūra – *Innovative Virtual European Transport Training Agency* (IVETTA).

IVETTA ir izglītojošs tīkls personām un institūcijām, kuras ir iesaistījušās transportapmācībā un izglītošanā un ir ieinteresētas to atbalstīt ar multimediju starpniecību un informācijas tehnoloģijām. Šī aģentūra koncentrējas uz transportapmācāmo un mācībspēku sekmēšanu ieviest jebkādus multimediju izglītošanas veidus, jaunas tehnoloģijas un kopīgus standartus viņu izglītošanās procesiem kā zinošiem patērētājiem un kompetentiem vadītājiem, vai arī kļūt par entuziasma pilniem multimediju attīstītājiem.

IVETTA stratēģiskais mērķis ir palielināt kvalitāti un drošību visiem transporta veidiem pēc augstas kvalitātes standartiem ilgtspējīgā izglītošanā un apmācībā un kopējā apmācības tīklā, ražošanā un apkopes organizācijās.

Rakstā tiek parādīti galvenie mērķi, inovatīvas stratēģijas, nākotnes tīkla kooperācijas un rezultātu galvenās aktivitātes, kuras izstrādātu IVETTA.

Atslēgvārdi: transports, apmācība, izglītība

Paramonovs J., Kuznecovs A. Nogurumam pakļauta planiera uzticamība. Inspekcijas programmas kontrole. *TRANSPORT and TELECOMMUNICATION,* 10.sēj., Nr.2, 2009, 16.–25. lpp.

Rakstā tiek izskatīts inspekcijas programmas attīstības algoritms un kontrole, lietojot Markova ķēdes teoriju, un p-rindas funkcijas definīcija, pamatojoties uz apstiprināta mūža testa rezultāta apstrādi. Autori izdara pieņēmumu, ka dažs Strukturāli Svarīgs Vienums (*angl.* Structural Significant Item (SSI)), kura kļūme ir visas sistēmas kļūme, tiek raksturots ar nejaušu vektoru (r.v.) (T_d, T_c), kur T_c ir kritisks mūžs (līdz kļūmei), T_d ir pakalpojuma laiks, kamēr kāds bojājums (noguruma plaisa) tiek atklāta. Autori arī pieņem, ka nepieciešamais sistēmas darbības mūžs ir ierobežots ar tā saucamo Specifisko Mūžu (*angl.* Specified Life (SL)), $\boldsymbol{t}_{SL}$, kad sistēmai netiek piemērots serviss. Daži piemēri tiek doti.

Atslēgvārdi: inspekcijas programma, Markova ķēdes, uzticamība

Pavļuks, D. Sakarības starp sabiedriskā transporta pieejamību un dzīvokļu cenām Rīgā statistiskā analīze**.** *TRANSPORT and TELECOMMUNICATION,* 10.sēj., Nr.2, 2009, 26.–32. lpp.

Savstarpējās attiecības starp sabiedriskā transporta pieejamību un apdzīvotās zemes vērtību ir daudzu pētnieku degpunktā. Hēdoniskas cenas regresijas modelis, kas tiek plaši lietots šajā pētnieciskajā laukā, kam ir viens ļoti svarīgs trūkums – tas aprēķina faktoru "vidējo" ietekmi uz zemes vērtību analizējamajā laukā. Parasti telpiska rakstura rezultātus parāda informācijā un sabiedriskā transporta pieejamības ietekme var tikt sadalīta pa rajonu nevienveidīgi.

Šajā pētījumā autori pielieto salīdzinoši jaunu regresijas modeļa modifikāciju – ģeogrāfiski izsvērtu regresiju, – lai izpētītu savstarpējo sakarību starp sabiedriskā transporta pieejamību un apdzīvotās zemes vērtību (īres un pārdošanas cenās) Rīgā. Piedāvātā metode ļauj, ņemot vērā telpiska rakstura rezultātus, parādīt savstarpējās sakarībās.

Autori izmanto informāciju par ģeogrāfisko vietu pilsētas sabiedriskā transporta pieturvietām un maršrutiem, lai aprēķinātu transporta pieejamības līmeni.

Kopā ar transporta pieejamības līmeni un kopīgu īpašību-specifikāciju parametru rindu (grīdas laukums, istabu skaits, etc.) mēs apskatām dzīvokļu izvietojuma papildu hēdoniskas īpašības, tādas kā attālums līdz supermārketam, augstskolām un dabīgie atraktīvi kā lieli parki, upes un pludmale.

Atslēgvārdi: ģeogrāfiski izsvērta regresija, hēdoniskas cenas modelis, sabiedriskā transporta pieejamība

Valkovjaks, T., Mazurkevičs, J. Diskrēto transporta sistēmu uzticamība un funkcionālā analīze ar modelēšanas un imitācijas palīdzību. *TRANSPORT and TELECOMMUNICATION,* 10.sēj., Nr.2, 2009, 33.–42. lpp.

Rakstā autori parāda jaunu pieeju diskrēto transporta sistēmu (DTS) analīzei. Piedāvātā metode tiek bāzēta uz sistēmas uzvedības modelēšanu un imitēšanu. Monte Karlo imitācija ir līdzeklis DTS darbības metriskam aprēķinam. Metodes galvenā priekšrocība ir sistēmas struktūras un sadales veida neierobežojums. Sistēma tiek aprakstīta ar formālu modeli, kurš ietver DTS funkcionālos parametrus un uzticamību. Rakstā tiek dots izveidotā stimulatora apraksts un tā darbības analīze.

Atslēgvārdi: uzticamība, diskrētā transporta sistēma, Monte Karlo imitācija

TRANSPORT
&
TELECOMMUNICATION

ISSN 1407-6160 & ISSN 1407-6179 (on-line)

Host Organizations:
Transport and Telecommunication Institute, Latvia – Eugene Kopytov, Rector
Telematics and Logistics Institute, Latvia – Igor Kabashkin, Director

Supporting Organizations:
Latvian Transport Development and Education Association
Latvian Academy of Sciences
Latvian Operations Research Society
Telecommunication Association of Latvia
Latvian Academic Park

All articles are reviewed.
Articles can be presented in the journal in English.

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Transporta un sakaru institūts (Transport and Telecommunication Institute)
Lomonosova iela 1, LV-1019, Riga, Latvia. Phone: (+371)67100594. Fax: (+371)67100535.
E-mail: kiv@tsi.lv, http:// www.tsi.lv

TRANSPORT and TELECOMMUNICATION, 2009, Vol. 10, No 2
ISSN 1407-6160
The journal of Transport and Telecommunication Institute (Riga, Latvia).
The journal is being published since 2000.

The papers published in Journal “Transport and Telecommunication” are included in **SCOPUS** (since 2008, Vol. 9, No 1), **Elsevier Database**
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