ISSN 1407-6160

TRANSPORT AND TELECOMMUNICATION

Volume 10. No 1

2009

Transporta un sakaru institūts
(Transport and Telecommunication Institute)

Transport and Telecommunication

Volume 10, No 1 - 2009

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

Riga – 2009

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 1
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

CONTENTS

Transport and Telecommunication, 2009, Volume 10, No 1, 4–13
Transport and Telecommunication Institute, Lomonosova 1, Riga, LV-1019, Latvia

HIEARACHICAL AGENT-BASED MODELLING: A GUADALAJARA CITY CASE STUDY ON URBAN TRAFFIC SIMULATION

Emmanuel López-Neri

Universidad del Valle de México, Campus Guadalajara Sur
Periférico Sur No. 8100 C.P. 45601
Guadalajara, Jal. México
emmanuel.lopezne@uvmnet.edu

In this paper a microscopic discrete event urban traffic model validation using simulation is presented. In a previous study a hierarchical microscopic urban traffic system (UTS) model was developed [1]. That model integrates the event oriented and agent-based approach. The UTS is described using the multi-level Petri net based formalism, named n-LNS. The first level describes the traffic network; the second level models the behaviour of diverse road network users considered as agents, and the third level specifies detailed procedures performed by the agents, namely travel plans, tasks, etc.. Usually simulators are designed using time step approach and are validated using real data and is verified that the flow/density relationship (fundamental diagram) are conserved and then state the simulator generates a valid behaviour. However, the model used in this paper uses the event oriented approach, doing more complex the process to obtain these validation graphs and their corresponding analysis. In order to validate it, was developed a library known as *CiudadelaSim* [1].

Keywords: discrete event, traffic simulation, microscopic validation, n-LNS, Petri nets

1. Introduction

An urban traffic system (UTS) is composed of vehicles, pedestrians, traffic lights, and a traffic network structure. The large number of the vehicles provokes well known problems such as traffic jams, air and noise pollution, fuel consumption, stress, etc. These problems may be reduced by the efficient use of current urban resources through the performance analysis under different traffic light control policies along the day. Model-based simulation is often used for evaluating UTS yielding statistics about travel times, fuel consumption, and road density; such information is useful to study traffic control strategies, urban transport routes, etc. Simulation has been increasingly adopted by the engineers and personnel charged to plan the signalling policies of the traffic network, in the literature there different approaches to model UTS exist [2].

Within the urban area, micro-simulation is better adapted for the analysis in detail of the vehicles behaviour, the performance of streets and intersections, and the effectiveness of traffic lights control strategies [2]. Under the micro-simulation approach an UTS can be considered as a discrete event system in which the simulation time advance is handled using the next event technique [5].

In this paper a previous study of hierarchical microscopic urban traffic system (UTS) model is used [1]. That model integrates the event oriented and agent-based approach. The UTS is described using the multi-level Petri net based formalism, named n-LNS. The first level describes the traffic network; the second level models the behaviour of diverse road network users considered as agents, and the third level specifies detailed procedures performed by the agents, namely travel plans, tasks, etc..

Usually simulators are designed using time step approach and are validated using real data and is verified that the flow/density relationship (fundamental diagram) are conserved and then state the simulator generates a valid behaviour. However, the model used in this paper uses the event oriented approach, doing more complex the process to obtain these validation graphs and their corresponding analysis. In order to validate it, was developed a library known as *CiudadelaSim* [1]. The system is open-source and free. *CiudadelaSim* may be downloaded at http://sites.google.com/site/ciudadelasimsite/. *CiudadelaSim* is not derived from any other toolkit, but rather was built from scratch using multi-agent event oriented principles. Our design philosophy was to build a fast, orthogonal, minimal model library to which an experienced Java programmer can easily add features, rather than one with many domain-specific, intertwined features which are difficult to remove or modify.

2. Urban Traffic System Components

The UTS entities or components are: network streets and intersections, road users (vehicle, pedestrians, cyclists, etc.), traffic signs (dynamic: traffic light, and static: speed limit sign) and individual and emergent behaviour (see Fig. 3).are classed into static and dynamic entities. Static entities cannot change their state, for instance traffic signals (speed limit, priority flow, etc.) or the street network. Dynamical entities or road users are objects that can move through the road network and/or change their own state, i.e., they have their own behaviour (cars, pedestrians, traffic lights, variable messages signs, etc.).

The road user behaviour is defined as a discrete event system. For instance, the relevant events for the entity named "vehicle" are advance, stop, accelerate, decelerate, change lane, and the states are stopped and advancing. Since in actual UTS the car drivers see other cars in their neighbourhood or field of view (FOV), then road users perceive the events of other dynamic entities in their neighbourhood.

Besides the description of the behaviour of dynamic entities, the evolving rules must be also specified. These rules govern the joint behaviour of entities. For instance, an evolving rule could be "two or more entities cannot be in the same space at the same time". The evolving rules are axioms that the UTS entities cannot violate. The interaction of one road user with other road users, static components, and traffic signs leads to more complex behaviours known as emergent behaviours, for example: queues, traffic jams, gridlock, green wave, etc. [6]. This emergent behaviour is not explicitly captured in the model, but it will be appear when the UTS model evolves, for instance, when a micro-simulator is used. The knowledge about queues, traffic jams, etc., allow to road users making better decisions during their execution.

The road network is a set S of interconnected streets and intersections called segments; it contains the travelling road users the dynamic and static traffic signals. These interconnections are defined by the following two relations:

The segment is the UTS environment basic modelling unit. Each segment represents a network structure road where the entity could displace in a sequential way. The entity may find physical obstacles during their displacement or caused by obey certain traffic policies; among other informative objects. Only one direction at time is allowed in each intersection. In this way, each intersection segment can contains only one vehicle at time. Also, the use of some segments is restricted to a certain kinds of entities.

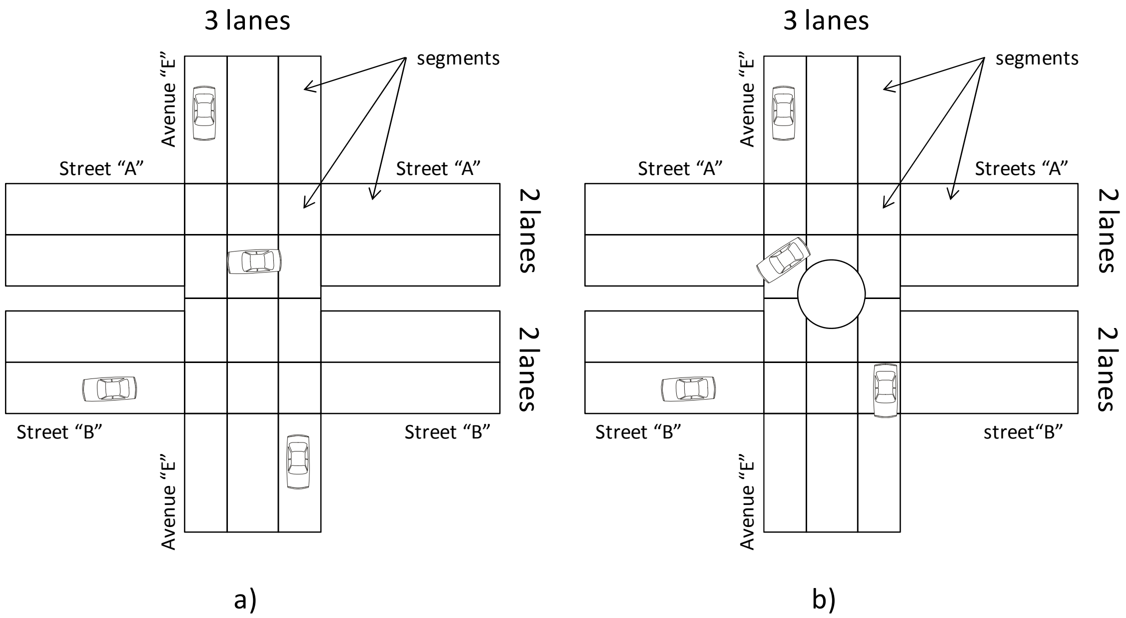


Figure 1. Urban traffic network description using segments a) Intersection b) Roundabout

Definition An object ***obj$_i$*** is a 3-tuple defined by ***obj$_i$*** = ($type_i$, $value_i$, w_i) where:

- $type_i \in$ {*staticSignal, variableMessageSign, bump, trafficLight, stopSignal*}.
- $value_i$ is the information provided to the entity, such that $value_i \in \aleph$.
- w_i is the object relative position at segment, such that $w_i \in \Re^+$.

Definition 1. A segment s_i is a 5-tuple defined by $s_i = (O_i, typeS_i, a_i, b_i)$ where:

- $O_i=\{obj_j\}$ is the set of objects in the segment *i*.
- $typeS_i \in \{use_{vehicular}, cross_{pedestrian}, exclusive_{bus}, exclusive_{train}\}$ represents the segment restrictions use.
- $a_i,b_i =(lat_i,long_i)$ y $lat_i,long_i \in \Re$, which are the geometric coordinates (latitude y longitude) that describe the segment endpoints on a map.

The next relationships allow to establish the connections between segments:

Relation 1. Sequential Neighbourhood. $NS = \{(s_i, s_j) \mid s_i s_j \in S$, the entities can displace sequentially from segment s_i to segment s_j, adding it to the tail end of $s_j\}$. If $\exists(s_i, s_j)\in NS \rightarrow \exists(s_j, s_i)\in NS$, since the relationship NS describes the physical connection between segments.

If the entity's ability to make a change lane is modeled then is added the following relation:

Relation 2: Contiguous Neighbourhood $NC = \{(s_i, s_j) \mid s_i s_j \in S$, the entities can displace in a parallel way from s_i to s_j and be added in any segment position$\}$. If $\exists(s_i, s_j)\in NC \rightarrow \exists(s_j, s_i)\in NC$, since the relationship NC describes the physical connection between segments.

3. Urban Traffic System Model based on n-LNS

The UTS model is expressed with n-LNS using three levels. In the first level the road network is described, the general behaviour of the road users is specified by level 2 nets; then the tasks or procedures needed to implement specific behaviours of the road user are represented by nets of level 3. Figure 2 shows the hierarchical UTS description using n-LNS.

The formalism follows the approach of nets within nets introduced by R. Valk [24], in which a two level nested net scheme called EOS (Elementary Object System) is proposed. An extension to the Valk's technique, called n-LNS, has been proposed [23]; in this section we present an overview of n-LNS. A more accurate definition of the formalism is detailed in [23]. In the next section is presented the UTS model using n-LNS, for a detailed information refer to [1].

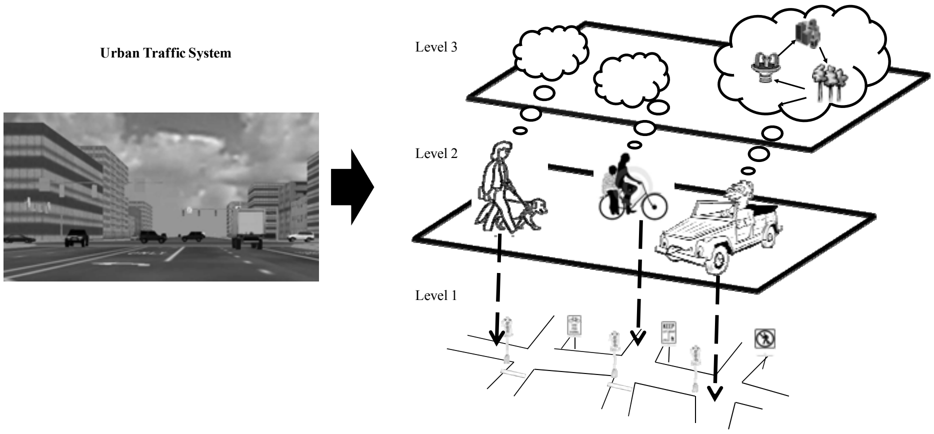


Figure 2. Hierarchical urban traffic system abstraction levels using n-LNS

First Level: The road network

The road network model can be straightforward obtained. For every segment $s_i \in S$, a place p_i is assigned. Then one transition t_{ij} is added for every (s_i, s_j) in *NC* or *NS*, together with arcs (p_i, t_{ij}) and (t_{ij}, p_j). Furthermore some transitions t_i must be added for every segment s_i source or sink; arcs (t_i, p_i) or (p_i, t_i) are added accordingly. Using this strategy the resulting model $typeNet_{1,1}$ ($EnvironmentNET_1$) for the traffic network showed in Figure 3, the static traffic signals for instance speed limit, bumps position, segment size, are information sent to the agent when a *leavSeg* transition is fired (*t06, t17*, etc.).

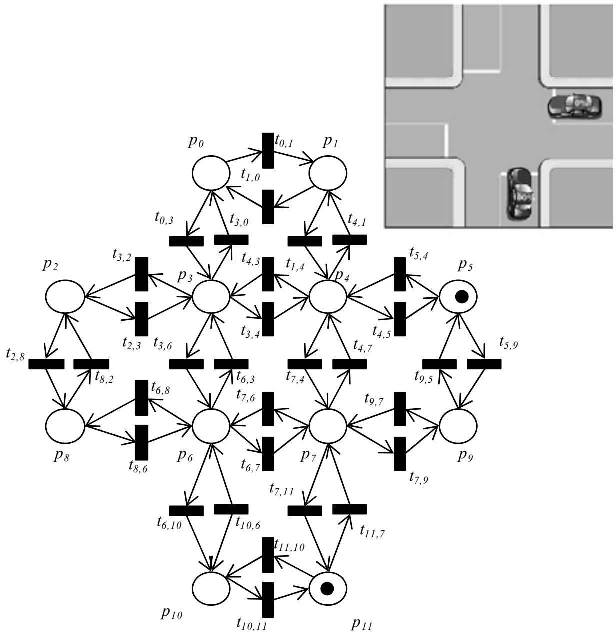


Figure 3. Road Network described with type net *EnvironmentNET*$_1$

Second Level: Agents

The decision making mechanism (DMM) of an agent is described by the net *typeNet*$_{2,1}$ showed in Figure 4. During the reasoning process, the evolving rules and traffic policies are taken into account.

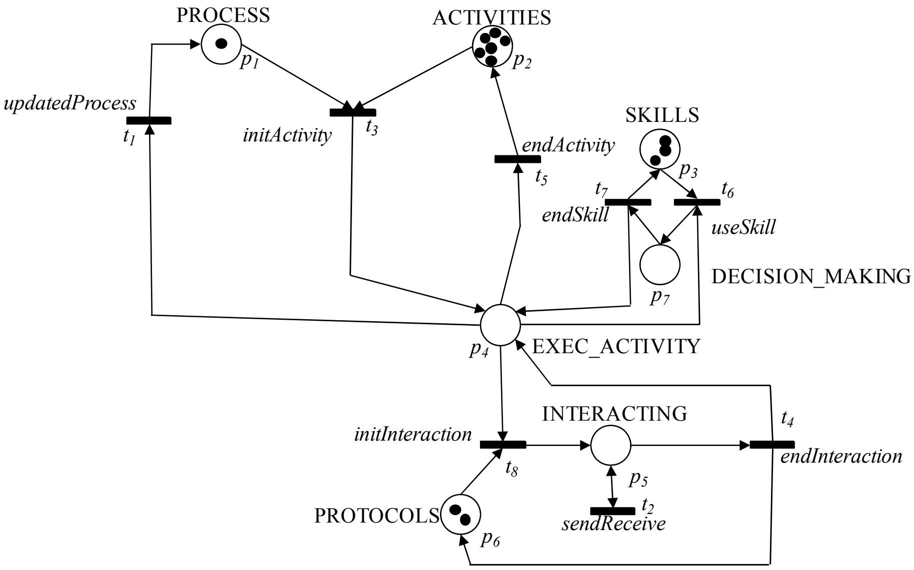


Figure 4. Decision Making Mechanism Described by typeNet$_{2,1}$

Third Level: Objects

Agent activities can be described by a third level net. In Figure 5 shows the *typeNet*$_{3,1}$ that describe the vehicle driver activities and its possible states. If a in *typeNet*$_{3,1}$ transition is fired, then a fact is modified. Each transition (agent event) modifies some of the agent facts; for instance the *endChLn* transition modifies the position fact. These events start a DMM cycle. For other dynamical entities in the UTS, the behaviour can be also represented by level 3 nets.

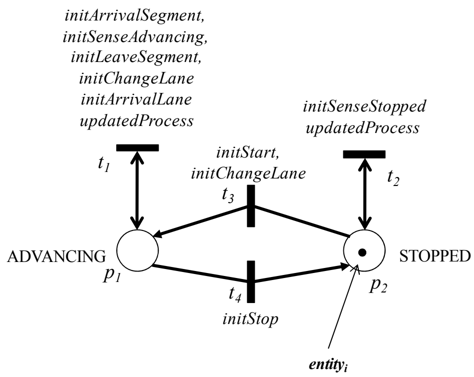


Figure 5. Vehicle Activities Described by typeNet$_{3,1}$

4. Simulator Implementation

CiudadelaSim library is the UTS n-LNS model implementation using Java™. This library provides to the computer programmer the necessary classes to implement a specific traffic model using the multi-agent paradigm. This library can be substituted, partially changed or increased to test new techniques or paradigms in an easy way. The *CiudadelaSim* library provides all the classes needed to implement different types of driver's behaviours as well as the models for the main driving task: car following, gap acceptance, and lane change. We have used a modular approach allowing each component to be easily redefined and extended.

A simulation is an instantiation of the classes from the *CiudadelaSim* library with the corresponding parameters to a specific experiment. The simulation can provide output statistics of each segment, as well as global network statistics. The results of the simulation and the links occupation ratios are obtain easily. Also a XML interface is provided to describe the UTS models using UTYiL language for the data model [6]. In Figure 1 the correspondent library architecture is shown.

The library consists of five distributed modules: the car generator, traffic light control, simulation kernel, visualization and static analyser (see Figure 6). These modules are distributed along the network. In order to distribute the simulation is used a connectivity software *ProActive* known as *middleware* [7]. The *middleware* allows a clear communication between different computers connected into a network (Internet, Intranet, etc.).

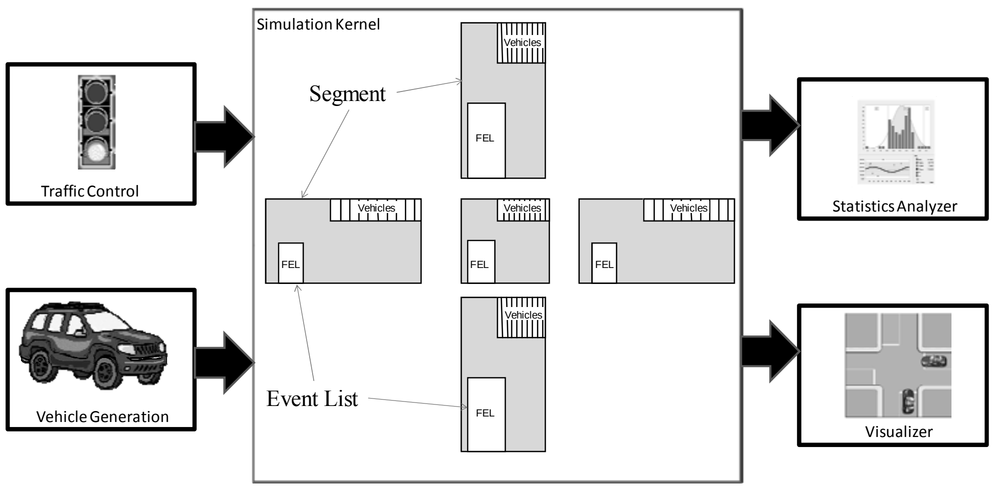


Figure 6. CiudadelaSim Architecture

In Figure 7 the simulator class diagram is depicted. The *carGenerator*, *ligthControl*, *Analyzer*, *Visualisation*, *SimulatorControler* and *StreetController* classes implement the Proactive interface *RunActive*, this allow each module be distributed along the network.

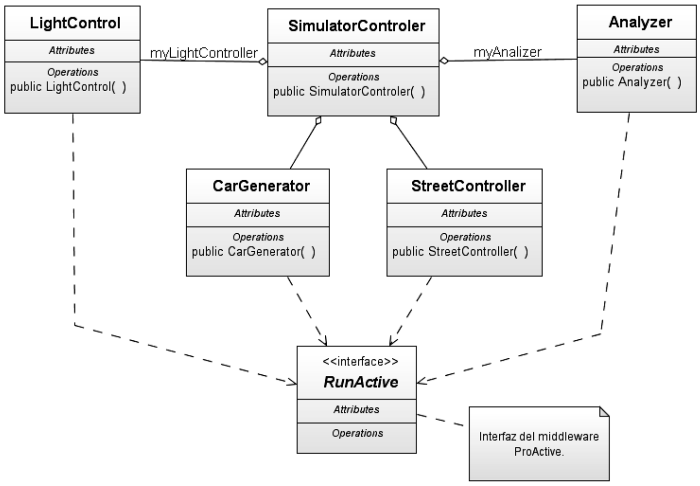


Figure 7. *CiudadelaSim* UML class diagram

The *SimulatorController* class creates instances of all other classes, read the UTS description model and generates the required data structures. The class *carGenerator* use a *Poisson* distribution to generate new vehicle events. This class sends the new events to the correspondent *StreetController* FEL structure. The *ligthControl* class generates new change light events for each tf_i in the traffic network structure. The *Visualization* class reads output from each simulation and graphically show the entity movement. The *Analyzer* class also reads output from each simulation but use them to obtain results statics for density, flow and travel times for each segment.

The *StreetController* class executes the events of each segment concurrently, but taking care of the causality rules. In this class the *runActivity()* method could be modified to evaluate distinct execution strategies. The space is subdivided by sequential sets of events (SQS) assigned to each segment. The potential event (event with minor timestamp) of each segment is ordered in a potential event list so could be executed in a distributed and concurrent approach. In Figure 8 is shown the future event lists and potential event lists data structures.

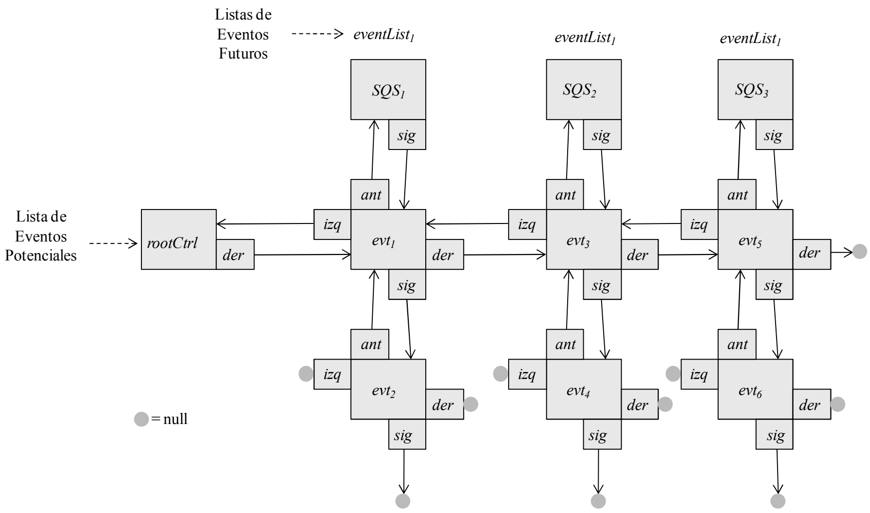


Figure 8. Future event list and potential event list data structure implementations

5. Case Study Description

Using the *CiudadelaSim* library a microscopic urban traffic simulation is run. The modelled area consists of 38 streets (one lane) of a vehicular traffic network section (see Figure 9). The traffic is regulated by traffic lights (tf_i) at each intersection. Each tf_i control the vehicle flow from street s_i. The study site is located at the downtown of Guadalajara city, so it experiences heavy congestion even during non-peak periods.

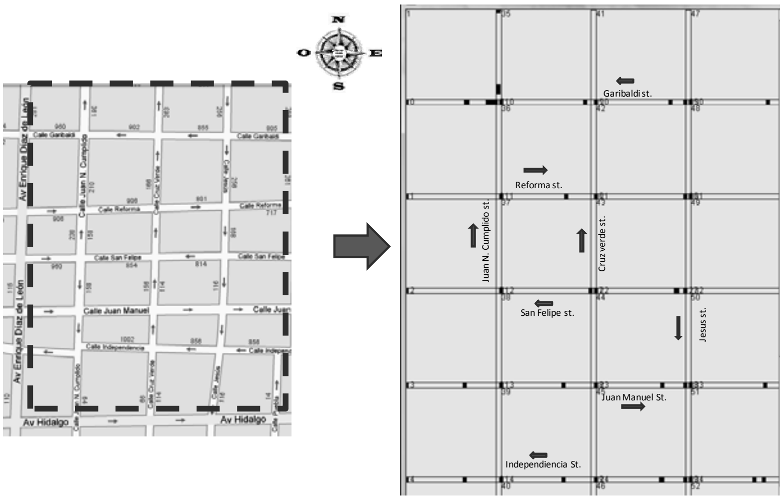


Figure 9. Segment road system of an Guadalajara town

Traffic Control

The possible vehicle paths at the intersections, subdivided by the phases of the traffic light control system, are shown in Figure 10. In the first phase, the traffic lights are green for vehicular flows incoming from sides A and C and red for flows incoming from sides B and D. In the second phase, the lights are green for sides B and D and red otherwise.

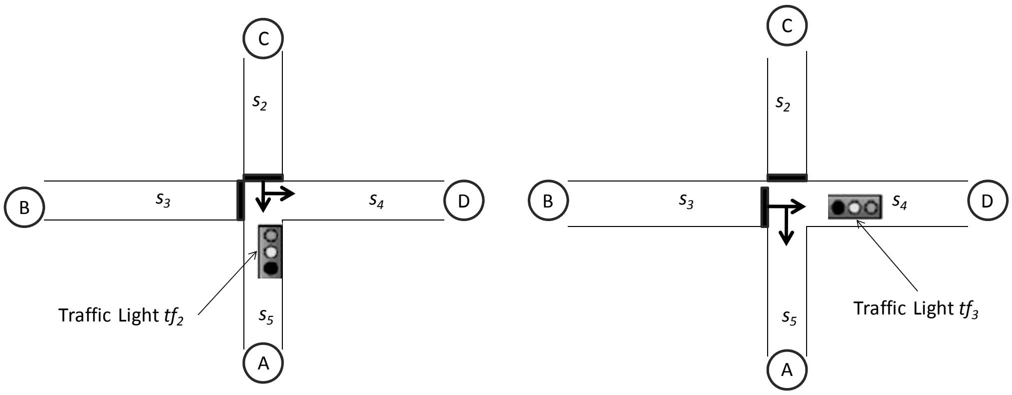


Figure 10. Scheme of vehicular paths of the traffic lights phase one

The Figure 11 depicts the four different control strategies used during the simulation run. In the first 600 seconds the strategy A is used; after 600 seconds the strategy B is used; finally strategy C is used.

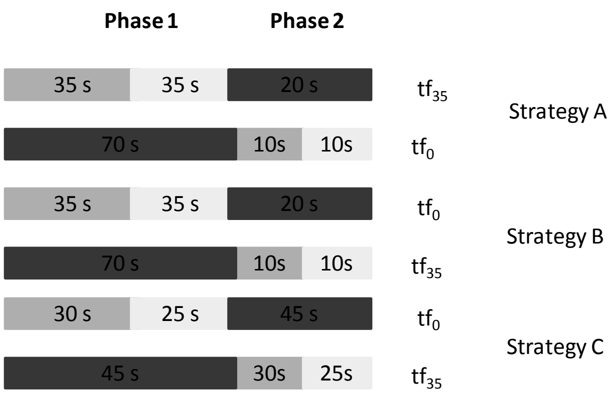


Figure 11. Traffic Light control strategies used in simulation

Vehicle Generation

In order to create new entities as the road users, a list of source segments are specified in the population generation system. In the case study the segments 0, 1, 3, 35, 32, 34, 46 y 47 are source segments. The model used in this research is a *Poisson* distribution, but could be substituted by real demographic data. The Poisson distribution is noted by the formula:

$P(n)=((\lambda t)^n e^{-\lambda t}) / n!$,

where:

$P(n)$ is the probability of exactly n vehicles arrive at time t

λ is the average arrival rate (*veh*/ *min*)

t is the duration of time over which the vehicles are counted

Output Data Model

CiudadelaSim generates the file *log.dat*. This file contains the event execution of the simulation. In Table 1 is shown the format used. The first field (*objectID*) contains the unique number identification for each vehicle; *evtime* field contains the event execution time; the *segment* field contains the segment id where the event was executed; the *evPos* field contains the segment position where the event was executed and finally the *evtype* field contains the event type that was executed using the next symbology 1=**SE** (stop Event),2=**CE** (Cross Event), 3 = **LCE** (Light Change Event), 5 = **CLE** (Change Lane Event), 6 = **CLEE** (Change Lane End Event), 7 = **ALE** (Arrival Link Event), 8 = **LLE** (Leave Link Event), 9 = **BE** (Begin Event), 10 = **AE** (Arrival Event), 11 = **WSE** (Warning Event for stop), 12 = **WBE** (warning Event for start). Figure 1 depicts the example of use.

Results Analysis

The Analyzer class generates the field flowdensity.dat as shown in Figure 1. This file is generated reading the file generated by the simulation, each time an event type equal to 7 is read then increments the *numberOutVehicles* variable and when the event type is equal to 8 then the *numberInputVehicles* variable is incremented. Then is calculated the density (space of a segment equal to 100 mts used on an instant time) and flow in each segment using the next equations:

flow = *numberOutputVehicles / numberInputVehicles*
density = *numberInputVehicles – numberOutputVehicles*

The calculated values for each second are stored in the file *flowdensity*.dat as shown in Table 1.

Table 1. FlowDensity.dat sample file format

Density Value	Flow Value
11.0	0.35294117647058826
11.0	0.35294117647058826
12.0	0.3333333333333333
11.0	0.3888888888888889
11.0	0.3888888888888889
11.0	0.3888888888888889
11.0	0.3888888888888889

Using the calculated values of table 1, then is obtained a plot with axis X the density values and Y axis the flow values.

Control Strategies Change

The simulator allows defining different control strategies (see Figure 11). In Figure 12 is shown the segments st_0 and st_{35} density-flow relationship. The st_{35} maintains high flow levels (and respectively low density) than st_0. This behaviour is generated when the strategy A is used, since the stop time is greater than green time for st_{35}. That increases the saturation of st_0. Although there is a change strategy, 600 seconds after , there is no enough time to reduce density of st_0, then continue with high density values. The change of phases provokes the instability of the diagram. The *x* axis shows the density and *y* axis the flow. Observe how the fundamental diagram of flow-density is conserved.

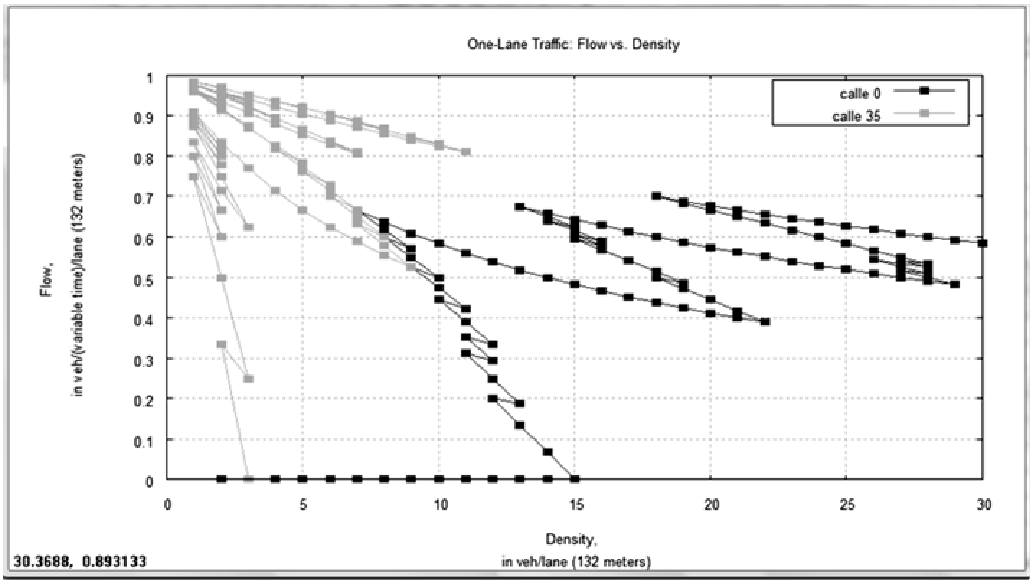


Figure 12. Flow-Density relationship diagram for st_0 and st_{35} segments

Individual Parameters Change

The *carGenerator* class allows to generate vehicles with different attributes or parameters such as: preferred velocity, safe distance, perception-reaction time, etc. In Figure 13 is shown the density of segment st_2 using distinct perception-reaction parameters. In Figure 1a the perception-reaction time parameter is equal to 0.2 min. The observed density increment is caused by the queue of vehicles when the traffic light turns red. When the traffic light turns green the density decrease and only some fluctuations appear in the density value. In Figure 1b is used a perception-reaction time equal to 8 min. Although the traffic light changes to green, the vehicle will delay 8 min. before start. This will convert the vehicle in an obstacle. Then the segment will increase exponentially their density.

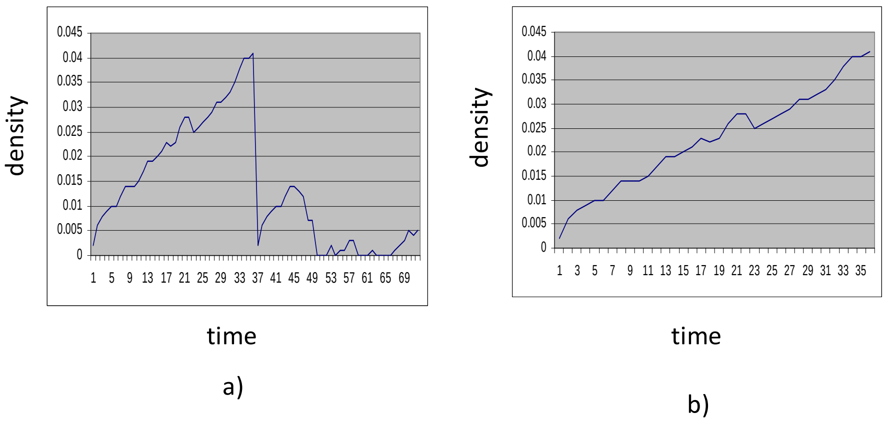


Figure 13. Density graphics for different perception-reaction times a) 0.2 minutes b) 8 min.

6. Conclusions

In this paper a hierarchical modelling framework for the simulation of urban traffic systems validation is presented. Simulation is a powerful tool for traffic managers that allow them to study and evaluate many traffic control strategies in order to implement the best one. Thus, is proposed a modelling framework that allows capturing systematically both the urban traffic network and the users' behaviour. The system model is a modular specification that provides the knowledge used by a micro-simulation engine based on a multi agent approach in which the vehicles are represented individually by mobile agents. A UTS description contains several formal models expressed in a three level Petri net formalism allowing selecting the microscopic desired level of road user behaviour and verifying the correct functioning of the desired behaviour before the implementation. The model is validated implementing *CiudadelaSim* library. *CiudadelaSim* is a java application that implements the n-LNS UTS model components. Future research includes the distribution of the simulation kernel.

References

1. 1 Lopez-Neri, E., Lopez-Mellado, E. and A. Ramirez-Treviño, Microscopic Modelling Framework for Urban Traffic Systems Simulation. In: *The 7th International Conference on System Simulation and Scientific Computing*. Beijing, China, 2008.
2. Barceló, J. *Microscopic traffic simulation: A tool for the analysis and assessment of ITS systems*, 2001.
3. Barceló, J., Ferrer, J. L. and D. García. *Microscopic traffic simulation for ATT system analysis. A parallel computing version. University of Montreal Contribution to the 25th Anniversary of CRT*, 1998.
4. Barclay, W. J. Point-to-Point microscopic simulation: a discussion of issues. In: *Proceedings of the First Western Pacific and Third Australia-Japan Workshop on stochastic models*. Christchurch, New Zealand, 1999.
5. Perumalla, K. S. A Systems Approach to Scalable Transportation Network Modelling. In: *Proceedings of the 2006 Winter Simulation Conference*, vol. 0, 2006, pp. 1500-1507.
6. Lopez-Neri, E., Lopez-Mellado, E. and A. Ramirez-Treviño. Un lenguaje para la descripción de la información geográfica de sistemas de tráfico urbano. In: *IV Semana Nacional de Ingeniería Electrónica*, Aguascalientes,Ags., 2008.
7. Baude, F. et al., Grid Computing: Software Environments and Tools: In: *Programming, Deploying, Composing, for the Grid / J. C. Cunha and O. F. Rana, Eds.* Springer-Verlag, 2006.

Transport and Telecommunication, 2009, Volume 10, No 1, 14–19
Transport and Telecommunication Institute, Lomonosova 1, Riga, LV-1019, Latvia

A STATISTICAL SAMPLE ANALYSIS OF LATVIAN LOGISTICS SERVICES

Gennady Gromov

Transport and Telecommunication Institute
Lomonosova Str. 1, Riga, LV-1019, Latvia
E-mail: gromov@tsi.lv

In the analysis are represented collected data, poll opinions and their interpretation of Latvian logistics service. The focus was made for three groups of companies: manufacturing/construction companies, trading companies, logistics service providers. In research mainly analyzed micro, small and medium size enterprises. The important Latvian logistics costs (transportation, warehousing, administration) and their trends are compared with similar US logistics characteristics. The results are used in LogOn Baltic project

Keywords: logistics, costs, indicators

In 2006-2007 in the framework of LogOn Baltic project [1, 2] were collected and analysed some poll opinions and statistics of logistics service in Latvia. Three versions of the survey have been used, focusing on the following three types of companies: 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.

According to the purposes of researches (fig. 1), the attention was mostly drawn to medium and small businesses, and this fact is confirmed with their shares in the sample: small companies (including micro) – ~84%, medium size companies – ~13% and their sum – ~ 97% total. This fact also reflects the general economic situation in Latvia. As stated by the Lursoft company (http://www.lursoft.lv/?a=16&v=en) at the end of the year 2006 in the Latvian National Enterprise Register there were near 210 thousands registered companies. Near 50 thousands of registered companies are active (really working, unsleeping) companies. The micro, small and medium size companies are near 99% of the mentioned above active companies. The Latvian small and medium size enterprises (SMEs) do more than 65% of gross domestic product (GDP) and have about 75% of all the employed persons. The number of Latvian companies per a thousand of Latvian inhabitants is about 20 and it is near two times less than the same average number in European Union.

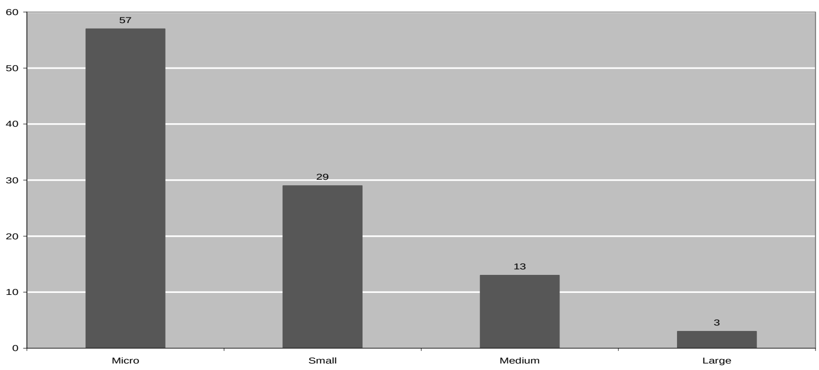


Figure 1. Number of respondents according to company size

Businesses in the sample are also classified by their main activities according to the targets of researches: ~38% are logistic providers, ~34% – trade companies and ~28% - manufacture companies (fig.2). This time this way of enterprises distribution is typical for Latvia to some extent, because during the last years the logo and slogan of Latvian business and government circles and the one of main Latvian economical directions is “Latvia is the country of transit and the West – East (gateway) bridge”. This kind of companies distribution can be supported indirectly by statistical data from the 2006 Statistical

Yearbook of Latvia. The year 2005 gross domestic product indices of Manufacturing, Trade and Transport are 106.3%, 117.4%, 116.2% accordingly (see table N2-6, p.19). It is required to take into account that in the mentioned above official Latvian source the data are given in accordance with the EU used Statistical Classification of Economic Activities (NACE Rev. 1.1). As the Head of Economic Board of Riga City Council, Mr I. Graurs said on TransBaltica 2007 (June 15, 2007) conference the 2006 year distribution of economic segments in Riga is following: trade – nearly 21%, transport and logistics – nearly 19% and manufacture – nearly 18%. It is additional support of right data structure of the survey.

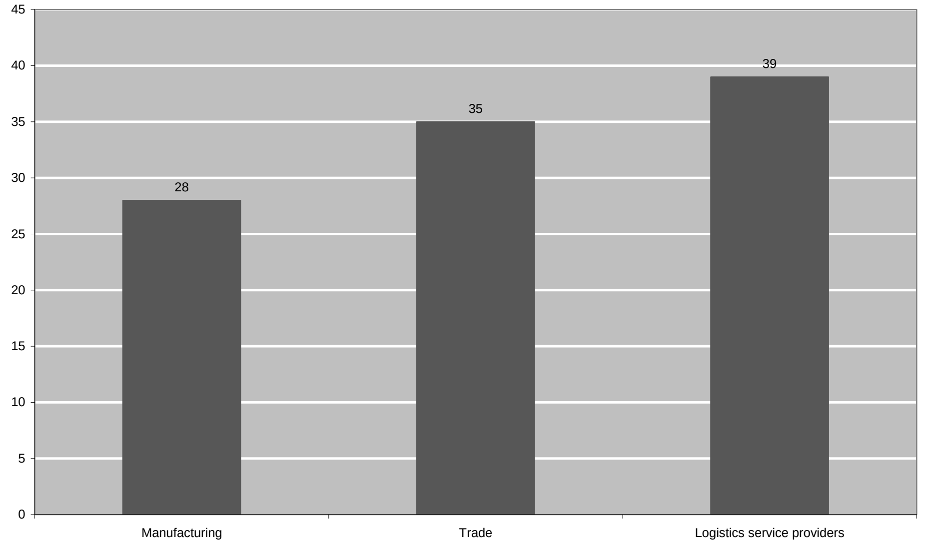


Figure 1. Number of respondents according to main industry

Manufacturing companies (fig. 3) that have incoming and outgoing material flows believe that the price of transport and warehouse services will increase (more than 80% of respondents' answers). Other logistic services will become more expensive as well – more than 50% of people interrogated agree with that. Only the category of expenses, which is connected with stock, in 50:50 percentage means both insignificant growth and insignificant reduction of stock expenses. This reflects the global tendencies that are connected with the use of Just-In-Time - technology, improvement of planning and respective reduction of stock.

First of all these conclusions of Latvian respondents based on the real fact of constant world oil price growth during the last ten years. In Latvia, for example (http://www.nra.lv/index.php?rid=52283), during last eight years petrol price increase is about 100%, exactly 97%. The last year increased prices of all energy resources (petrol, gas, electric energy). The survey answers reflect this situation.

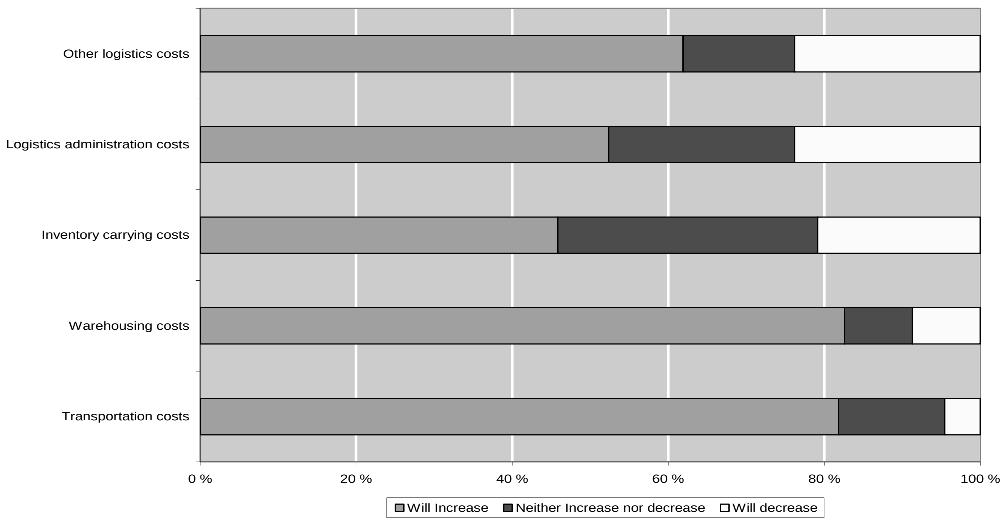


Figure 3. Estimate of the development of logistics costs, manufacturing companies

There is a high level of agreement among the trading businesses (fig. 4). More than 50% of respondents suppose that all types of logistic expenses will rise, and more than 90% of companies think that transport costs will grow. Unlike manufacturing companies, trading companies consider that stock expenses will also grow, which can be explained by the specific character of this sphere.

The explanation of the costs increase trend opinion of Latvian trade companies is the same as for Latvian manufacturing companies. The inventory cost growth can be also explained as the result of competition (fighting for clients) between small trade, supermarkets and electronic trade (E-commerce).

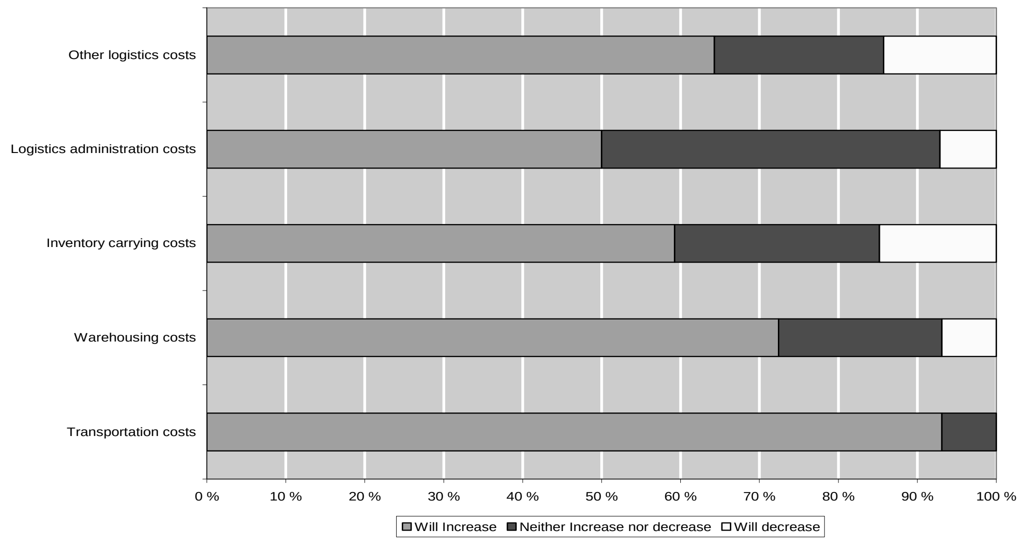


Figure 4. The estimate of the development of logistics costs, trading companies

Such inferences and trends are supported by more then 30-years US logistics statistics [3-6] (fig.5). Practically the same data and relations are true for European Logistics too [7].

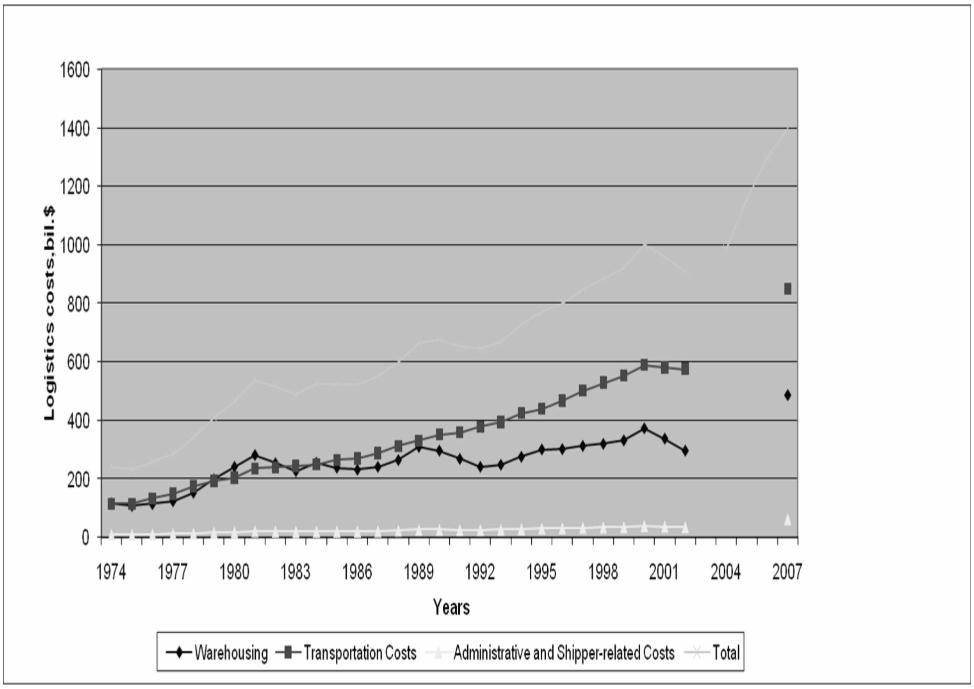


Figure 5. US Logistics costs statistics [5–7]

90% of respondents mark the necessity of the improvement of transport management. 60% indicate the necessity of basic logistic education development. 30% consider that the basic knowledge of supply chains is necessary. 20% mark the necessity of the improvement of stock management. Special skills are specified within the 10% range (fig. 6). The necessity of language improvement and innovative management was not mentioned at all. The manufacturing companies are connected with the manufacturing schedule and the matter of sharp transport performance is extremely important for them. That should be especially noted in conditions of heavy traffic, which is typical for Riga and Riga district, as well as in the situation of systematical last two – three years traffic jams at the Latvian – Russian border, that is European Union – Russian Federation border. That is why the experienced logistic workers, who deal with transport issues correctly and secure the accuracy of production, are important for the businesses mentioned above.

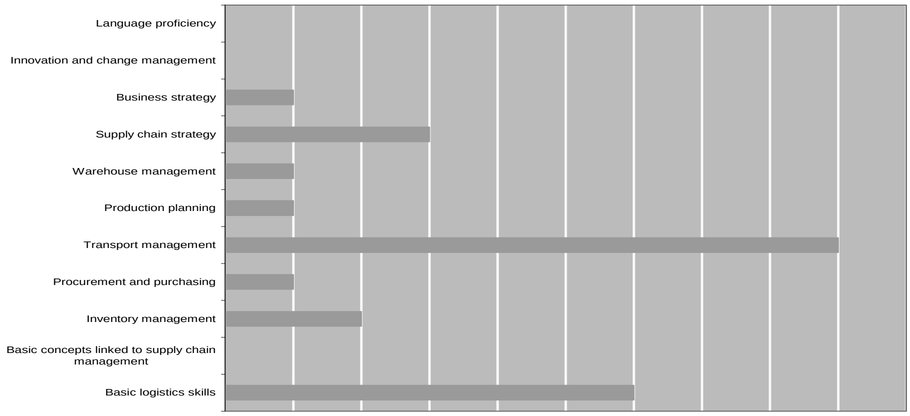


Figure 6. The development needs of personnel competence, manufacturing companies

There is a totally different situation in trade. The majority of respondents agree that it is necessary to develop almost all types of logistic competence (the preference is given to basic knowledge of logistics (60%), business strategy (50%), planning (50%), inventory management (40%) and supply chain management (40%) (fig.7). If there are no answers about transport management, it usually means that companies generally do not have own cargo transport. Transport for them is usually *outsourcing*. The trade companies also take care of personnel language proficiency (20%) and innovation and change management (10%). Partly or indirectly the fact of mentioned above logistic competence necessities can be confirmed by some changing tendencies in Latvian Education System. The main part of universities and Higher Education Institutes and colleges (state and private) has developed special Logistics educational programs. During last two–three years it was prepared the total about one thousand professionals in the sphere of Logistics. Some of them in addition to knowledge of native language know one or two foreign languages.

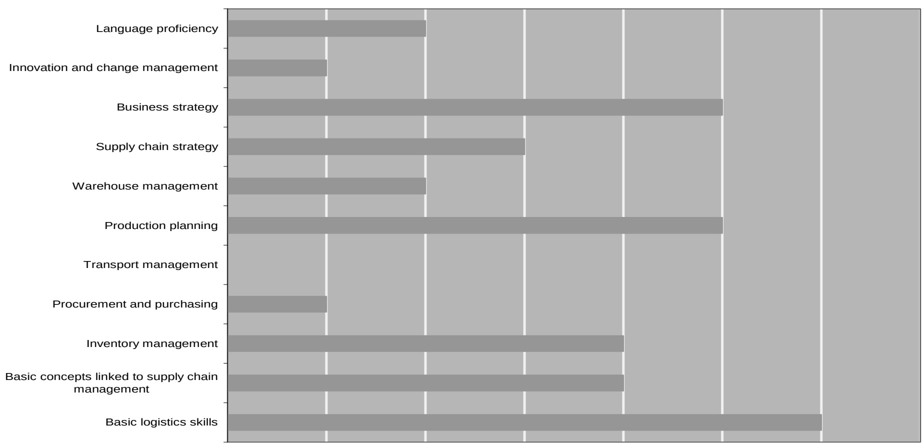


Figure 7. The development needs of personnel competence, trading companies

The share of the companies that use international and local transport as *outsourcing* is up to 90%, while warehouse and forwarding facilities – up to 70% (fig.8). Near to 30% of companies use order processing, invoicing, inventory management and product customization as outsourcing procedures. In the sphere of logistic information technologies – up to 10%. The volume or extent of using is different. It varies from 1% to 100% in different companies. Approximately the same outsourcing logistics operations statistics was discussed on the International Federation of Warehousing Logistics Association Annual Convention 2006 "Eastern Europe – New Logistics Resources", that was in Riga on May–June 2006. All these results could be interpreted from three points of view:

a) the main part of companies in the sample are small and micro size and for this reason they do not have enough financial resources for outsourcing;

b) outsourcing operations in Latvia especially for application to service small size firms do not develop their service in relevant manner.

c) it is possible that potential clients do not understand the real value and profit of using represented and advertised on Latvian market outsourcing logistics services.

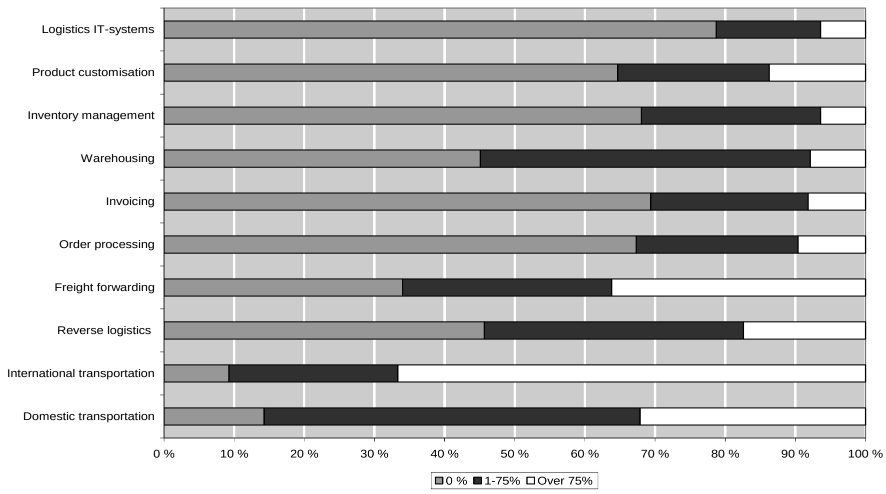


Figure 8. Outsourcing of different logistics functions, companies in Latvia

As the result of the last analysis it is possible to see (fig. 9) great positive tendencies (relative trends) in the development of *outsourcing* on the Latvian market. Opportunities are seen in the sphere of logistics information technologies – up to 80%, in order processing and product customisation – up to 30%. There are some growth reserves (up to 20%) in forwarding, inventory management, reverse logistics and warehouse facilities

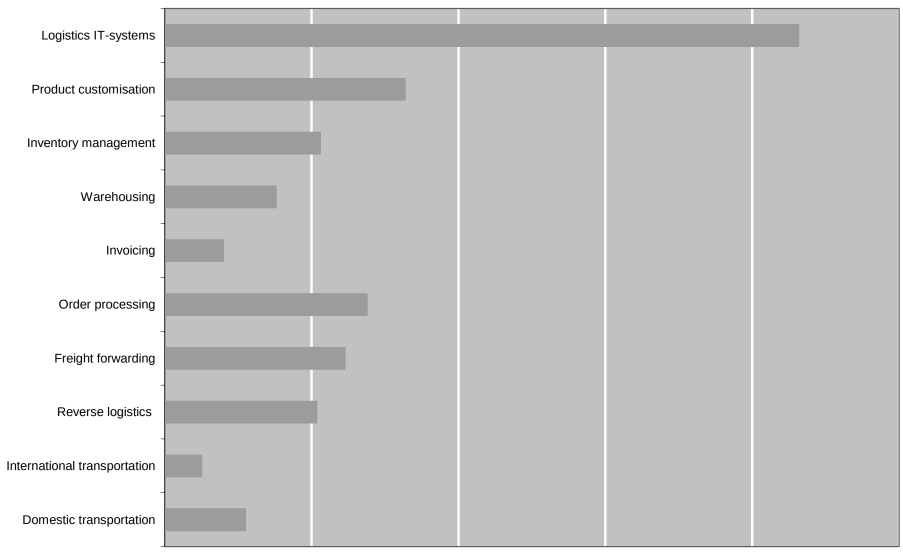


Figure 9. The relative trend of outsourcing, companies in Latvia

Some of the aspects of logistics research (logistics cost, logistics indicators a.c.) will be analysed in the future, taking in attention last events and data [8, 9].

Conclusions

The selected statistical data of the survey, which was carried out in Latvian enterprises, has been analysed. In connection with the fact that the main subject of the survey was logistics, which is practiced practically by every Latvian enterprise to certain extent, it may be supposed that the results of the survey reflect the majority of vital characteristics and problems of logistic service in Latvia.

1. The opinions of businessmen from three economy branches – production, trade and logistic service – are reflected in the survey.
2. The opinions of companies with different production output (large, medium, small and micro) are reflected in the survey as well. Medium and small (including micro) enterprises are shown more representatively in the sample. That complies with the aim of the survey and reflects common proportions of distribution of the universal set of Latvian enterprises by production output.
3. The questions were answered mostly by middle and top managers and experts, that is, managers with rather high qualification and working experience, so the answers may be considered suitable for the real situation in Latvian logistics.
4. Manufacturing and trading companies suppose that logistics expenses will grow.

References

1. http://info.tse.fi/logonbaltic/
2. Solakivi? Tomi. *Finland State of Logistics 2006*, the fourth national logistics survey, Note N4 – www.logonbaltic. Info
3. Bowersox, D. J., Closs, D.J., Cooper, M. B. *Supply Chain Logistics management.* 2007 The McGraw-Hill, Inc., 680 pp.
4. Malone, R. *Logistics Costs Soar* – http://www.forbes.com/logistics/2006/07/18/logistics-costs-soaring-cx_rm_0718costs.html
5. Logistics Costs and U.S. Gross Domestic Product (Prepared for: Federal Highway Administration Department of Transportation Prepared by: MacroSys Research and Technology Washington, DC, August 25, 2005, – http://ops.fhwa.dot.gov/freight/freight_analysis/econ_methods/lcdp_rep/index.htm
6. Blanchard, D. U.S. Logistics Costs Hit Record High – http://www.industryweek.com/ReadArticle.aspx?ArticleID=17017&SectionID=11
7. European Logistics Policy. The Maritime Dimension. European Association for Forwarding, Transport, Logistics and Custom Services (CLECAT) AMRIE's High Level Conference 2008, 5-6 June 2008, Valencia – http://www.clecat.org/dmdocuments/ps003omama080605confamrie.pdf
8. Warren H. Hausman, Hau L. Lee, Uma Subramanian Global Logistics Indicators, Supply Chain Metrics, and Bilateral Trade Patterns FIFTH DRAFT – October 10, 2005
9. The GMA 2005 Logistics Survey Supply chain performance in food, grocery and consumer products IBM Business Consulting Services, 28 p.

Transport and Telecommunication, 2009, Volume 10, No 1, 20–29
Transport and Telecommunication Institute, Lomonosova 1, Riga, LV-1019, Latvia

BENCH DEVELOPMENT OF NAVIGATION ALGORITHMS BY APPLICATION OF OBJECT-ORIENTED TECHNOLOGIES

Alexander Chernodarov

Research & Production Company "OPTOLINK" Ltd
Proezd 4806, 5, 124498, Moscow, Zelenograd, Russia
E-mail: chernod@mail.ru

Special features of implementing an object-oriented technology for the integration of navigation sensors in strapdown inertial satellite systems(SISNS) are considered. A block diagram of the object-oriented hardware support and object-oriented mathematical-software support for the SINS-1000 system built around fiber-optic gyros is given. The results of testbed experiments of the SINS-1000 system are presented, which corroborate the fact that it is possible and expedient to apply the proposed technology to the creation of different-purpose SISNSs which can be made to order.

Keywords: navigation systems, fiber-optic gyros, object-oriented technology, half-scale modeling

1. Introduction

The development of airborne equipment is characterized by the designing and introduction of integrated navigation systems (INSs). The necessity and expediency of creating such systems are connected with more rigid requirements that are imposed upon the navigational flight safety of aircraft (Acft). Integration of navigation systems (NSs) permits the following problems to be solved:

- maintenance of the continuity and global character of navigational determinations;
- maintenance of the required accuracy characteristics, reliability and integrity of the navigational determinations;
- combination, into a unified structure, of navigation sensors that vary in the operating principle and provision, on this basis, of NS mutual support;
- implementation of the integration capabilities of optimal estimation filters;
- provision of mutual testing and also of the counteraction of outliers and failures;
- maintenance of the required NS operational characteristics under varying noise conditions;
- reduction of the NS readiness time, etc.

The implementation of the INS potentialities requires that the computational process be adequately organized. Such an organization must exclude phase distortions and must provide the required frequency of determining the parameters of Acft motion.

In the present paper, an object-oriented technology intended for construction of the mathematical and hardware support of INSs is discussed. Such a technology involves tuning the hardware part to the problem being solved and also mapping the INS algorithms onto a measurement-computer environment (MCE), which is reconfigurable. The reconfigurable MCE permits the hardware and mathematical software of INSs to be developed operationally when both testbed experiments and full-scale experiments are carried out.

The purpose of this paper is to perform an analysis of the object-oriented technology for comprehensive development of onboard navigation algorithms and to demonstrate its capabilities when carrying out testbed experiments.

2. An Object-Oriented Technology for the Hardware Support of Integrated Strapdown Inertial Satellite Navigation Systems

At the "OPTOLINK" RPC (Zelenograd, Russia), the object-oriented technology is considered as a base one in the design of integrated strapdown inertial satellite navigation systems (SISNSs), which are built around fiber-optic gyros (FOGs) [1], in particular around the SINS-500 and SINS-1000 systems. Figure 1 shows a SINS-1000 system block diagram.

In these systems, the hardware tuning of a measurement-computer environment relies on the preliminary structuring of the algorithmic support and it is aimed at solving the following problems:

- based on the basic MCE architecture, provision of a possibility to implement different variants of SISNS organization, depending upon the object proper purpose, the required operational characteristics, and cost;
- sequential extension of the computational capability of an MCE kernel when various SISNS operating modes are implemented in a ripple-through fashion;
- provision of a possibility for multilevel hierarchical organization of the computational process;
- minimization of hardware expenditure on the basis of a modular integrated MCE architecture;
- provision of the possibilities for MCE reconfiguration and MCE adaptation to the ISNS and object operating modes on a basis of the unification of both hardware and software modules. The PC-104 standard has been taken as a base one in the design of a SINS series, which are built around FOGs;
- provision of a possibility for the preprocessing of digitized sensor information;
- provision of a possibility for the adaption of MCE interfaces to an object;
- provision of a possibility to implement all the computational procedures in the clock time that is established by the reference generator. Such a possibility can be realized on a basis of the following technological decisions:
  - data-flow RISC organization of the computational process;
  - buffering and paralleling of the input and output information;

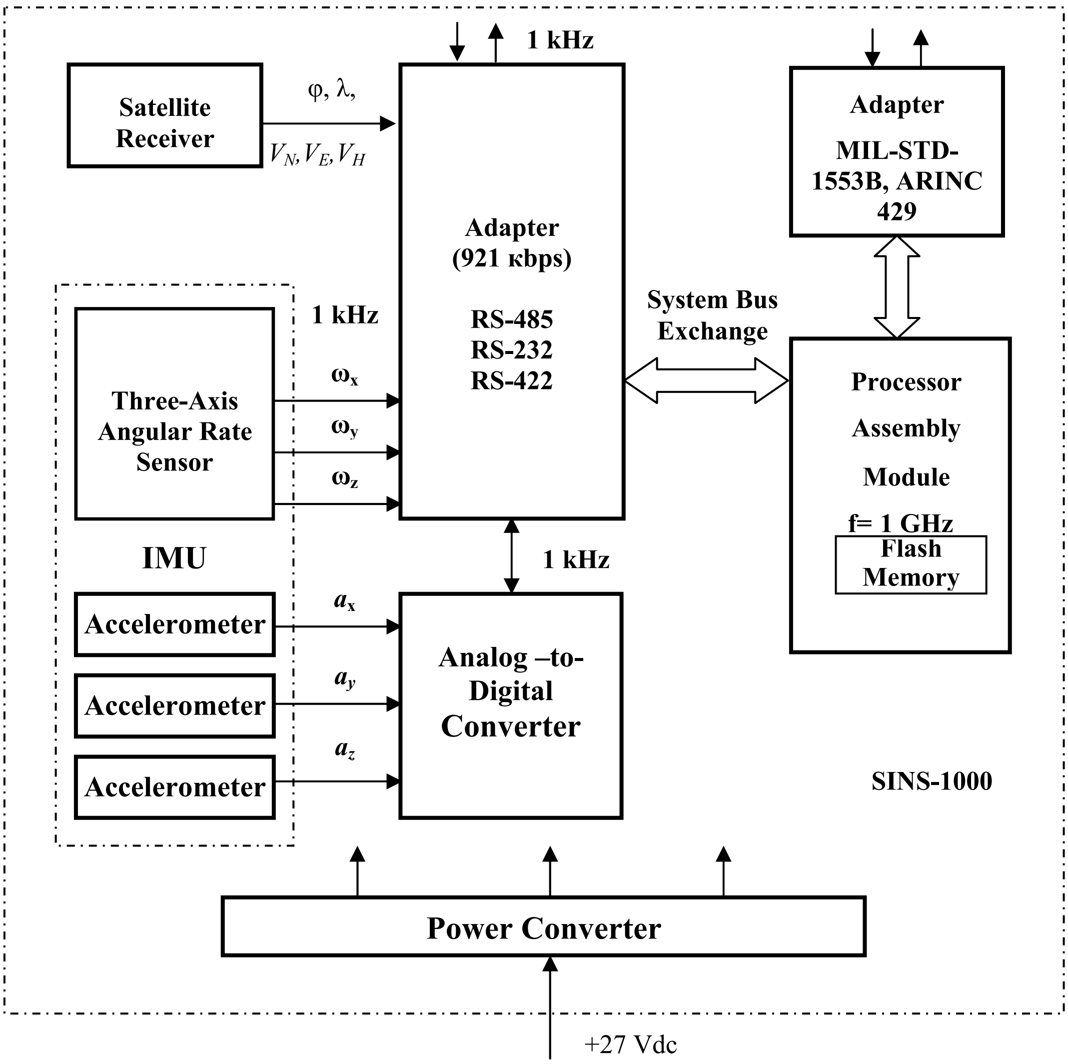


Figure 2. Block diagram of the SINS-1000 strapdown inertial satellite navigation system

- synchronization of the procedures for data gathering, data processing, and data recording at all hierarchies;
- use of the MCE system bus in order for data exchange among the SISNS modules to be accelerated.

3. An Object-Oriented Technology for the Mathematical-Software Support of Integrated Strapdown Inertial Satellite Navigation Systems

The object-oriented technology for a mathematical-software support (MSS) involves mapping the ISNS algorithms onto a reconfigurable measurement-computer environment. Such a technology relies on the solution of the following problems:

a) distribution of data gathering, data processing, and data recording problems among the MCE hierarchies;
b) structuring of the ISNS algorithmic support with the aim of carrying out 1) the unification of mathematical–software modules and 2) data-flow RISC organization of computations;
c) mapping of unified mathematical-software modules onto the MCE multilevel hierarchical structure;
d) making the procedures of primary and second processing of navigation sensor signals agree with the MCE computational capability;
e) increasing the degree of computational-process homogeneity on a basis of minimizing the number of tests and conditions.

In designing an MSS for the SINS-1000 system, the following object-oriented technological decisions have been used, which rely on tightly-coupled schemes for the damping of SINS errors [2]:

- homogeneity and data-flow implementation of algorithms for SINS autonomous functioning were achieved on the basis of solving quaternion equations separately for attitude parameters, for navigation parameters, and for their errors, i.e.,

$$2\dot{q}_0 = \Pi_0 q_0 ; \tag{1}$$

$$2\dot{q}_1 = \Pi_1 q_1 ; \tag{2}$$

$$\dot{x} = A(t)x(t) + G(t)\xi(t) , \tag{3}$$

where $q_0 = [q_o q_1 q_2 q_3]^T$ is a quaternion [3] that characterizes the angular position of the frame *oxyz,* which is fixed to the inertial measurement unit (IMU), with respect to the inertial frame $OX_I Y_I Z_I$ [4]; $q_1 = [\tilde{q}_o \tilde{q}_1 \tilde{q}_2 \tilde{q}_3]^T$ is a quaternion that characterizes the angular position of the wander azimuth reference navigation frame $o\xi\eta\zeta$ with respect to the Earth centered Earth fixed frame $OX_E Y_E Z_E$ [4,5].

$$\Pi_0 = \begin{bmatrix} 0 & \dot{\Theta}_y & -\dot{\Theta}_x & -\dot{\Theta}_z \\ -\dot{\Theta}_y & 0 & \dot{\Theta}_z & -\dot{\Theta}_x \\ \dot{\Theta}_x & -\dot{\Theta}_z & 0 & -\dot{\Theta}_y \\ \dot{\Theta}_z & \dot{\Theta}_x & \dot{\Theta}_y & 0 \end{bmatrix}; \qquad \Pi_1 = \begin{bmatrix} 0 & -\omega_\xi & -\omega_\eta & -\omega_\zeta \\ \omega_\xi & 0 & \omega_\zeta & -\omega_\eta \\ \omega_\eta & -\omega_\zeta & 0 & \omega_\xi \\ \omega_\zeta & \omega_\eta & -\omega_\xi & 0 \end{bmatrix};$$

$\bar{\dot{\Theta}} = \begin{bmatrix} \dot{\Theta}_x & \dot{\Theta}_y & \dot{\Theta}_z \end{bmatrix}^T$ is the vector of FOG output signals;

$\bar{\omega} = \begin{bmatrix} \omega_\xi & \omega_\eta & \omega_\zeta \end{bmatrix}^T$ is the vector of turn rates of the reference frame $o\xi\eta\zeta$ in the geodetic frame [6]. Moreover, for the wander azimuth frame, $\omega_\zeta = 0$. Components of the vector $\bar{\omega}$ are determined from the orthogonal components V_ξ, V_η, V_ζ of the ground velocity vector $\bar{V}$, which are taken from the solution of the basic equation of inertial navigation [7], i.e.,

$$\dot{\overline{V}} = C_2{}^T\ \overline{a} + \overline{g} - 2\overline{\Omega}\times\overline{V} - \overline{\omega}\times\overline{V} - \overline{\Omega}\times\left(\overline{\Omega}\times\overline{R}\right), \tag{4}$$

where

$\overline{V} = [V_\xi \quad V_\eta \quad V_\zeta]^{\mathrm{T}}$ – is the ground velocity vector of IMU motion, given by its components along the axes of the reference navigation frame $o\xi\eta\zeta$;

$\overline{a} = [a_x \quad a_y \quad a_z]^{\mathrm{T}}$ – is the vector of output signals of accelerometers;

$\overline{g} = [g_\xi \quad g_\eta \quad g_\zeta]^{\mathrm{T}}$ – is the vector of gravitational acceleration;

$\overline{\Omega} = [\Omega_\xi \quad \Omega_\eta \quad \Omega_\zeta]^{\mathrm{T}}$ – is the vector of the angular velocity of Earth rotation;

$\overline{R} = [0 \quad 0 \quad R]^{\mathrm{T}}$ – is the IMU position vector;

$(\times)$ – is the operator of vector product;

C_2 is the direction cosine matrix (DCM) which characterizes the angular position of the IMU-fixed frame *oxyz* with respect to the reference frame $o\xi\eta\zeta$, and the above matrix is determined from the elements of the quaternions q_0, q_1 and from the angle $\Omega\Delta t$, where Δt is the time of SINS functioning. Furthermore, from the elements of these quaternions one can find the angles ψ, ϑ, γ of IMU angular position with respect to the local geodetic frame *oENH*, along with the geodetic latitude φ and geodetic longitude λ; Π_0, Π_1 are skew-symmetric matrices the signs of elements of which correspond to the IMU design; $x(t)$ is the vector of SINS errors.

Separate solution of Eqs.(1) and (2) has made it possible to bring the depth of estimation of SINS errors to the level of sensors: gyroscopes and accelerometers. The basic vector $x(t)$ was comprised of 17 parameters, namely: the errors $\Delta V_\xi, \Delta V_\eta, \Delta V_\zeta$ in the reckoning of components of the ground velocity vector, the errors Δq_0 and Δq_1 in the reckoning of quaternion elements, the angular drifts $\Delta\dot{\Theta}_x$, $\Delta\dot{\Theta}_y$, $\Delta\dot{\Theta}_z$ of FOGs, and the biases $\Delta a_x, \Delta a_y, \Delta a_z$ of accelerometers. Sensor error equations were formed in an IMU-fixed frame. This has enabled us to implement a tightly-coupled scheme for the damping of sensor errors, and the above scheme included a Kalman filter in the estimation loop;

$A(t) = \left.\dfrac{\partial F(Y,t)}{\partial Y}\right|$ is the matrix of partial derivatives;

$F(Y,t)$ – is a function that represents, in the general form, the right-hand sides of SINS equations (1),(2), (4) and sensor error equations;

$Y = Y(t)$ – is the vector of parameters that are determined by a SINS;

$G(t)$ – is the matrix for intensities of the disturbances $\xi(t)$;

- homogeneity and data-flow implementation of algorithms for the integration of a SINS and the GPS were achieved on a basis of the *W-D* technology [8] for observation processing. Procedures for such processing rely on an $U - D$ modification of the Kalman-Joseph filter, which is characterized by computational stability, and they result from the following identity:

$$P_{i/j} = W_{i/j}\overline{D}_{i/j}W^T{}_{i/j} \;= U_{i/j}D_{i/j}U^T{}_{i/j}\,, \tag{5}$$

where $P_{i/j}$ – is the value of the "a posteriori" covariance matrix of estimation errors at the i–th step, which is obtained after processing the *j*-th component of the vector z_i of observations;

$W_{i/j}$ – is an $n\times(n+j)$ rectangular matrix;

$\overline{D}_{i/j}$ – is an $(n+j)\times(n+j)$ diagonal matrix;

$U_{i/j}$ – is an $n\times n$ upper triangular matrix with identity diagonal elements;

$D_{i/j}$ – is an $n\times n$ diagonal matrix.

On the basis of identity (5), a *W–D* modification of the algorithm for adaptive robust processing of observations was implemented, which has the following form:

Prediction: $m_0 = \hat{x}_{i/i-1} = \Phi_i \hat{x}_{i-1/i-1}\,;$ (6)

$W_0 = \left[\Phi_i U_{i-1/i-1} \vdots \Gamma_i\right];$ (7)

$\overline{D}_0 = diag(D_{i-1/i-1}, Q_{i-1})\,;$ (8)

Tuning: $v_j = z_j - H_j m_{j-1}\,; \qquad \beta_j = \nu_j / \alpha_j\,;$ (9)

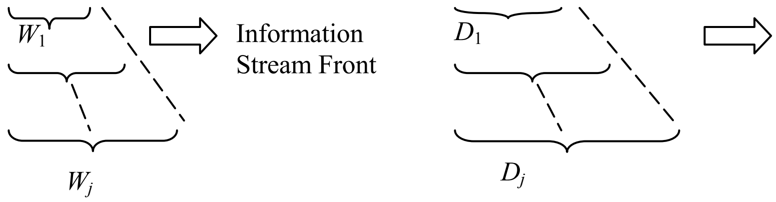
$\psi_j = \psi(\beta_j); \qquad \psi'_j = \psi'(\beta_j);$ (10)

Updating: $f_j = H_j W_{j-1}\,; \qquad V_j = \overline{D}_{j-1} f_j^{\mathrm{T}}\,;$ (11)

$\tilde{\alpha}_j = f_j V_j\, \psi'_j + \alpha_j^2\,; \qquad K_j = W_{j-1} V_j / \tilde{\alpha}_j\,;$ (12)

$m_j = m_{j-1} + K_j \alpha_j \psi_j\,; \qquad \hat{x}_{i/i} = m_l\,; j = \overline{1,l}\,;$ (13)

$W_j = \left\lfloor W_0 \vdots K_1 \vdots \ldots \vdots K_j \right\rfloor \qquad \overline{D}_j = diag(\overline{D}_0, \alpha_1{}^2 \psi'_1, \ldots, \alpha_j{}^2 \psi'_j)$ (14)



Orthogonal transformation: $MWGS\left\{W_l; \overline{D}_l\right\} \rightarrow U_{i/i}; D_{i/i}\,,$ (15)

where m_j , $\hat{x}_{i/i}$ are the estimates of the vector of SINS errors at the i-th step, which are obtained after processing the j-th component and the whole vector z_j of observations; α_j is a scaling parameter; Φ_i, Γ_i are transition matrices for the vector x_i of state and for the vector ξ_i of disturbances, respectively; Q_i is the covariance matrix for the vector of disturbances; ψ_j , ψ'_j are an influence function and its derivative [9], which set up the level of confidence in the incoming observations. These functions are formed with due regard for "a priori" assumptions made as to the distribution laws of the valid signal and noise, or the above functions are tuned in an adaptive way [10]; MWGS is the procedure [11], intended to transform the aggregate of matrices W_l and $\overline{D}_l$, which are an $n \times (n+l)$ matrix and an $(n+l) \times (n+l)$ matrix, respectively, into the aggregate of the $n \times n$ matrices $U_{i/i}$, $D_{i/i}$.

Data-flow organization of computations has enabled us to take the orthogonalization procedure (15) out of the basic loop of observation processing (9) – (14) and to execute it only once.

Algorithm (6) – (15) has been implemented at the level of primary and second processing of signals. Its place in the MSS structure for the SINS-1000 system is shown in Fig. 3, where Acc is the accelerometer triad; ARS is the triad of angular-rate sensors; DF is a digital filter; RKF is a robust W-D modification of the Kalman filter; CC is a coordinate converter; $\hat{x}_{\overline{a}}$ is the vector of estimates of the biases of accelerometer signals; $\hat{x}_{\overline{\omega}}$ is the vector of estimates of FOG drifts.

4. Analysis of the Results of Studies

The SINS -1000 integrated strapdown inertial satellite navigation system [12] that is built around the FOG -1000 fiber-optic gyros designed by the "OPTOLINK" RPC (Zelenograd, Russia) and also based on the K-161 satellite receiver developed by the "RIRT" JSC (Saint-Petersburg, Russia) has been the object of experimental studies.

Experiments have been carried out on the ground when the necessary equipment was placed on a test bed and then housed in a mobile laboratory. The timing diagram of SINS operation included the following stages: coarse initial alignment, fine initial alignment, and a navigational mode. At the stage of coarse initial alignment, IMU angular position was approximately determined using sensor output signals. At the stage of fine initial alignment, estimation of and compensation for both the errors of the angular position of IMU sensors and IMU sensor drifts were carried out by the sequentially processing of the observed signals z_i of the following form:

$$z_{\Theta(i)} = C_{0(i)}^{\mathrm{T}} \int_{t_{i-1}}^{t_i} \dot{\overline{\Theta}}(\tau)d\tau - \left[0 \vdots 0 \vdots \Omega\Delta t_i\right]^{\mathrm{T}} ; \tag{16}$$

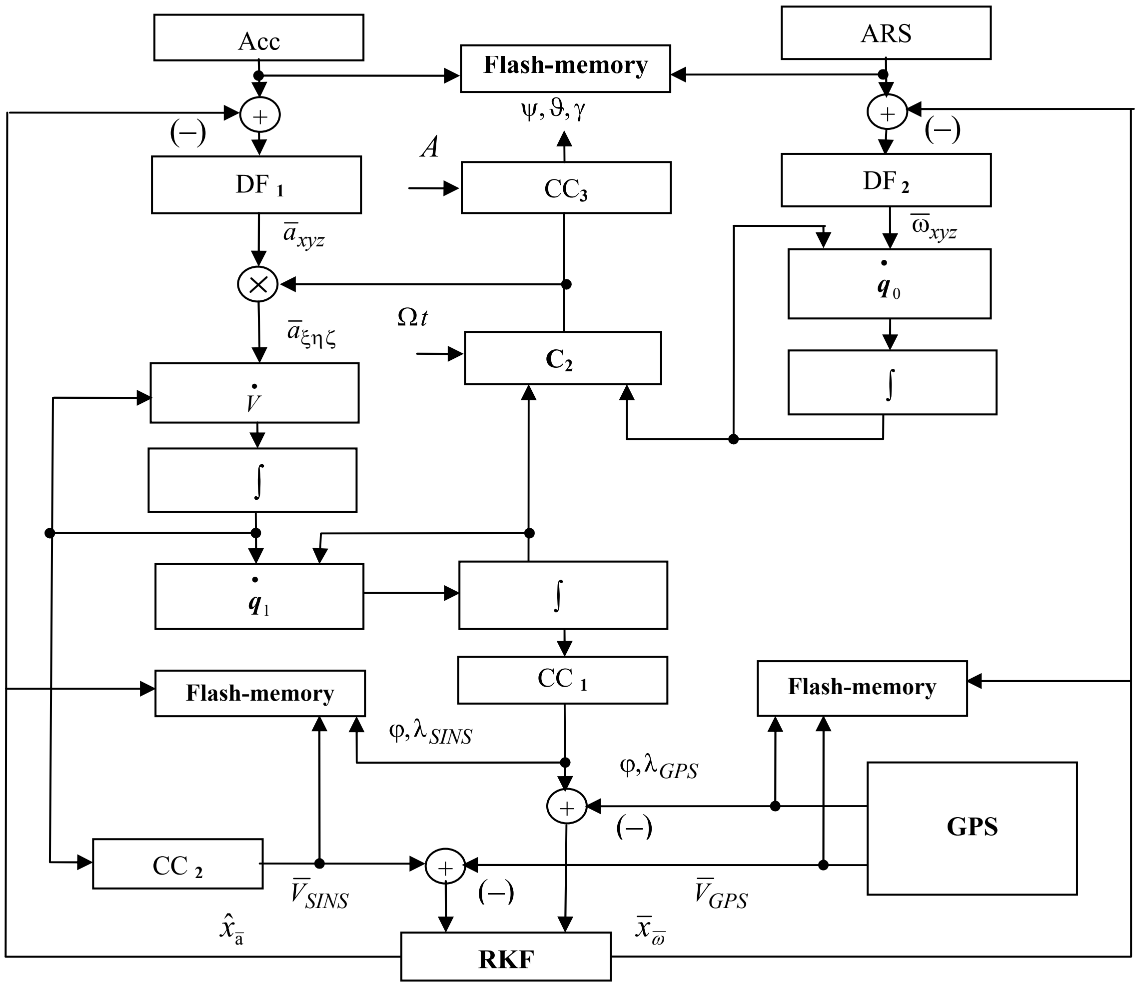


Figure 3. Block diagram of the mathematical-software support for the SINS-1000 system

$$z_{k(i)} = [\varphi_i \lambda_i]_{\mathrm{SINS}}^{\mathrm{T}} - [\varphi_i \lambda_i]_{\mathrm{FIA}}^{\mathrm{T}} ; \tag{17}$$

$$z_{\mathrm{v}(i)} = [V_\xi V_\eta V_\zeta]_{(i)\mathrm{SINS}}^{\mathrm{T}} , \tag{18}$$

where FIA stand for the position of fine initial alignment; φ_i, λ_i are the geodetic latitude and longitude of the SINS position; $\Delta t_i = t_i - t_{i-1}$ is an observation step, C_0 is the direction cosine matrix, which characterizes the angular position of the IMU-fixed frame *oxyz* with respect to the inertial frame $OX_IY_IZ_I$.

In the navigational mode, SINS errors were estimated and compensated for from position and velocity observations, i.e.,

$$z_{k(i)} = [\varphi_i \lambda_i]^{\mathrm{T}}_{SINS} - [\varphi_i \lambda_i]^{\mathrm{T}}_{GPS}; \tag{19}$$

$$z_{\mathrm{v}(i)} = C^{\mathrm{T}}_{3(i)} [V_\xi V_\eta V_\zeta]^{\mathrm{T}}_{(i)SINS} - [V_E V_N V_H]^{\mathrm{T}}_{(i)GPS}, \tag{20}$$

where C_3 is the direction cosine matrix that characterizes the angular position of the frame $o\xi\eta\zeta$ with respect to the frame *oENH.*

The results of a comparison analysis of SINS operation when using different schemes for the damping of sensor errors were obtained on a basis of the reckoning of motion parameters from the recorded signals of sensors such as the IMU and the GPS.

Certain of the results of a testbed experiment on the estimation of accuracy characteristics of the SINS 1000 system are shown in Figs.4-7. Figure 4 depicts the following signals: the output signal (a light-colored graph, arc secs/sec) of the "vertical" gyro; the output signal (a dark-colored graph) of the same gyro, which was smoothed by means of a robust digital filter [12]. In Fig.5, the following signals are shown: the output signal (a light-colored graph, m/sq.sec) of one of horizontal accelerometers; the output signal (a dark-colored graph) of the same accelerometer, which was smoothed with the aid of a robust digital filter. The above smoothing has been performed when sensor signals were picked off with a frequency of 1 kHz. Figure 6 depicts the FOG actual instrumental drift (deg/h), which is determined as the mean value of "zero" bias on the time intervals of 10 sec, and its estimate which was obtained both in the processing of observations (16)-(18) with a frequency of 1 Hz during the fine initial alignment (100-600 sec) and when predicting such an estimate in the navigational mode with the aid of algorithm (6). In Fig.7, an estimate of the accelerometer bias is shown. Beginning with the moment t=600 sec, the SINS-1000 system was functioning in the autonomous inertial mode. Figures 8-11 show errors in the reckoning of the ground velocity ΔV and circular error in the object position ΔS. Figure 8 reflects the dynamic behavior of the ground velocity error when sensor drifts are damped, and Figure 9 reflects the above behavior when the sensor drifts are not damped. Figure 10 reflects the dynamic behavior of the circular error in the object position when sensor drifts are damped, and Figure 11 reflects the dynamic behavior of the circular error in the object position when sensor drifts are not damped, where

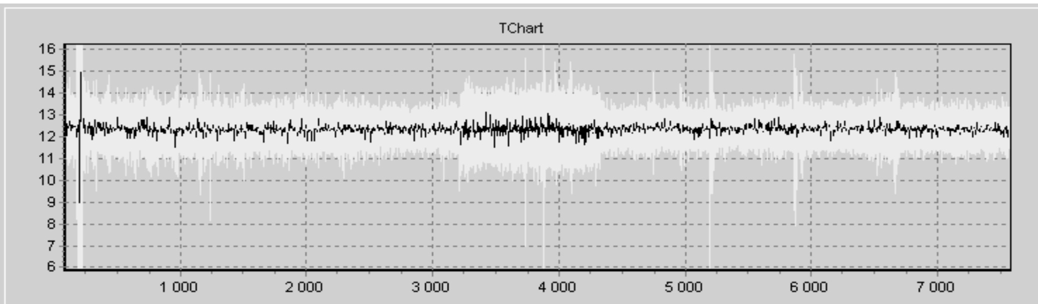
$$\Delta S = \sqrt{\delta_\varphi{}^2 + \delta_\lambda{}^2}; \quad \Delta V = \sqrt{\Delta V_E{}^2 + \Delta V_N{}^2}; \quad \delta_\varphi = (\varphi_{\mathrm{SINS}} - \varphi_{\mathrm{GPS}})R; \quad \delta_\lambda = (\lambda_{\mathrm{SINS}} - \lambda_{\mathrm{GPS}})R$$

$R= a(1-0,5e^2\sin^2\varphi)$; a=6378245 м; e^2 = 0,0066934; [7]

$$\Delta V_E = V_{E(SINS)} - V_{E(GPS)}; \Delta V_N = V_{N(SINS)} - V_{N(GPS)}; V_{E(\mathrm{SINS})} = V_\xi \cos A - V_\eta \sin A; \quad V_{N(SINS)} = V_\xi \sin A - V_\eta \cos A;$$

A is the azimuth angle of the reference frame $o\xi\eta\zeta$ with respect to the local geodetic frame *oENH.*

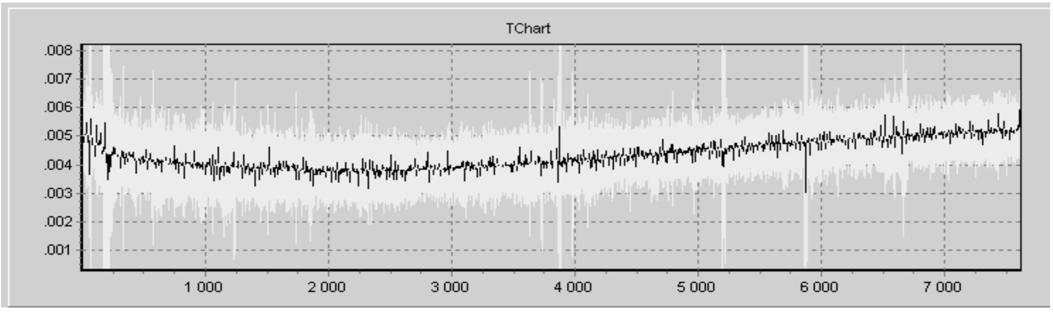
$\dot{\Theta}$, $\hat{\dot{\Theta}}$, *arc sec/sec*



t, sec

Figure 4. Output signal of the "vertical" gyro

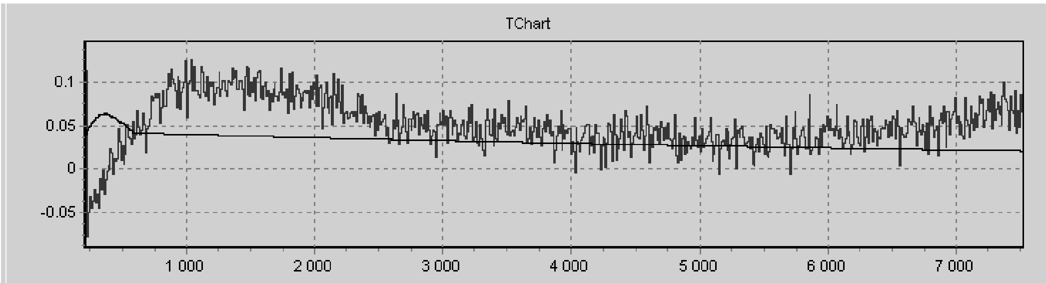
a_x , m/sq.sec



t, sec

Figure 5: Output signal of one of horizontal accelerometers

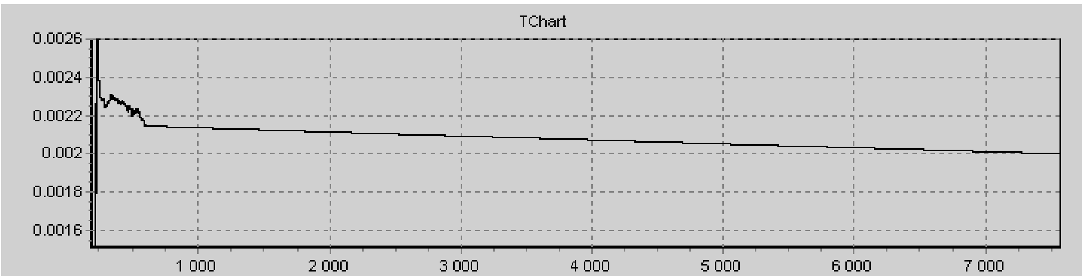
$\Delta\omega_z$, *arc deg/h*



t, sec

Figure 6. FOG instrumental drift and its estimate

$\Delta \hat{a}_x$, *m/sq.sec*



t, sec

Figure 7. Accelerometer bias estimate

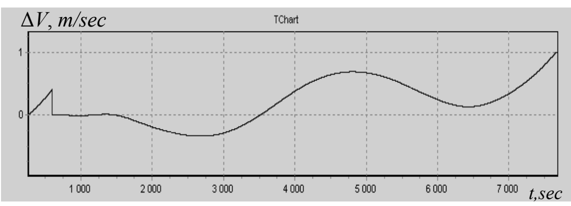


Figure 8. Dynamic behavior of the errors of the ground velocity when sensor drifts are damped

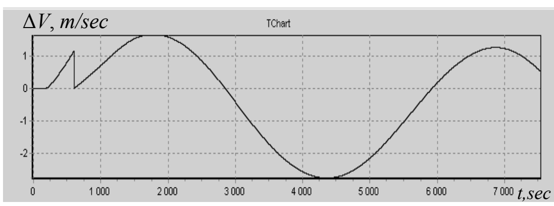


Figure 9. Dynamic behavior of the errors of the ground velocity when sensor drifts are not damped

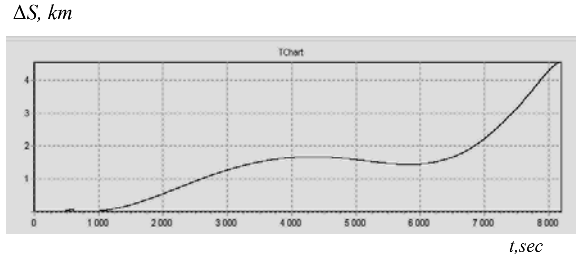


Figure 10. Circular error of the object position estimate when sensor drifts are damped

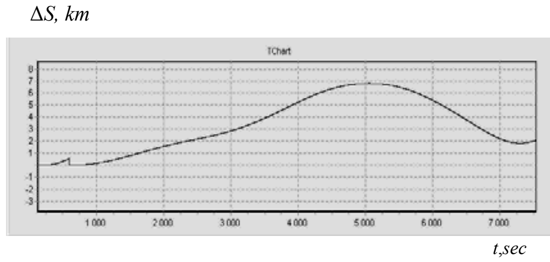


Figure 11. Circular error of the object position estimate when sensor drifts are not damped

The studies conducted have corroborated the fact that it is effective to apply the object-oriented technology to the creation of SINSs which can be made to order.

5. Conclusions

In the paper presented here, an object-oriented technology for the integration of navigation sensors is considered. Such a technology is closely connected with systems approaches to the design of different-purpose airborne equipment according to the cost-effectiveness criterion. The employment of the above technology in creating the SINS-1000 strapdown inertial satellite navigation system built around fiber-optic gyros is demonstrated. Systems design of the mathematical-software support and hardware support (MSS&HS) for the SINS-1000 system has been performed beginning with the problem that is the most consuming one in the sense of computational resources, i.e., the problem of the integration of navigation sensors at all the hierarchies. In this case, it is apparently possible to keep the MSS&HS organization unchanged when different attitude parameters and different navigation parameters are used and also when mathematical models of sensor errors are updated.

Object – oriented computational tools permit the following problems to be solved: implementation of a unified technological process meant for the development of onboard algorithms with the use of mathematical and half – scale models, and also when testbed and full – scale experiments are conducted; unification of the procedures for interfacing the object under study with information channels of onboard and ground – based computers.

References

1. Udd, E. *Fiber Optic Sensors. An Introduction for Engineers and Scientists.* New York: John Wiley & Sons Inc., 2006. 518 p.
2. Chernodarov, A.V., Patrikeev, A.P., Bulgakov, S.L., Mikheenkov, Yu.P., Golyaev, Yu.D, Kolbas., Yu.Yu. Improvement of the Operational Characteristics of Integrated Navigation Systems on the Basis of Tightly-Coupled Schemes for the Damping of Sensor Errors. In: *Proceedings of the 13th International Conference on Integrated Navigation Systems. Saint Petersburg, Russia, May 29-31, 2006, Central Scientific and Research Institute «Electropribor».* Saint-Petersburg: CSRI «Electropribor», 2006, pp. 111-119.
3. Titterton, D.H., Weston, J.L. Strapdown Inertial Navigation Technology. *Progress in Astronautics and Aeronautics Series,* Vol. 207. Lexington, Massachusetts: MIT Lincoln Laboratory, 2004. 574 p.
4. *GOST 20058-80. Aircraft Dynamics in Atmosphere. Terms, Definitions and Symbols*. Moscow: Izdatelstvo gosstandartov, 1981. (In Russian)
5. Bromberg, P.V. *Inertial Navigation Systems Theory.* Moscow: Nauka, GRFML, 1979. 296 p. (In Russian)
6. GOST R 51794 – 2001. *Radionavigation Hardware for the Global Navigation Satellite System. Coordinate Systems*. Moscow: Izdatelstvo gosstandartov, 2001. 12 p. (In Russian).
7. Babich, O.A. *Data Processing in Navigation Complexes*. Moscow: Mashinostroenie, 1991. 512 p. (In Russian)
8. Chernodarov, A.V., Kovregin, V.N., Rogalev, A.P., Alakoz, G.M. Adaptive Robust Signal Processing on Homogeneous Computational Structures. In: *Proceedings of the International Conference "Methods and Microelectronic Means for Digital Conversion and Processing of Signals". Riga,*

Latvia, December 5-7, 1989, Latvian Academy of Sciences. Riga: IEVT AN LSSR, Vol. 1, 1989, pp. 357-359. (In Russian)

9. Chernodarov, A.V., Patrikeev, A.P., Budkin, V.L., Golikov, V.P., Larionov, S.V. Flight Development of Onboard Estimating Filters. In: *Proceedings of the 11th International Conference on Integrated Navigation Systems. Saint Petersburg, Russia, May 24-26, 2004, Central Scientific and Research Institute «Electropribor».* Saint-Petersburg: CSRI «Electropribor», 2004, pp. 27-35.
10. Chernodarov, A.V., Patrikeev, A.P., Platonov, A. Ju., Budkin, V.L., Golikov, V.P., Larionov, S.V. Parametric Identification of Integrated Navigation Systems in Real Time and from Flight Data, *Gyroscopy and Navigation,* No 4 (59), 2007, pp. 17-31. (In Russian)
11. Bierman, G.J. *Factorization methods for discrete sequential estimation*. New York: Academic Press, 1977. 320 p.
12. Korkishko, Yu.N., Fedorov, V.A., Chernodarov, A.V., Patrikeev, A.P., Perelyaev, S.E. Multilevel processing of fiber-optic-gyro signals in strapdown inertial navigation systems. In: *Proceedings of the 15-th International Conference on Integrated Navigation Systems. Saint Petersburg, Russia, May 26-28, 2008, Central Scientific and Research Institute «Electropribor».* Saint-Petersburg: CSRI «Electropribor» , 2008, pp. 51-53.

Transport and Telecommunication, 2009, Volume 10, No 1, 30–37
Transport and Telecommunication Institute, Lomonosova 1, Riga, LV-1019, Latvia

DEVELOPMENT OF THE SYSTEM OF ROAD TRAFFIC SAFETY IMPROVEMENT IN ACCIDENT SEATS OF URBAN AREAS

Denis Kapskij

Belorussian National Technical University
Nezavisimosty avenue, 65, Minsk, 220013, The Republic of Belarus
Tel.: +375 2312968. Fax: +375 2373631. E-mail: OAPDD@BNTU.BY

The analysis of the developed system of increase of road traffic safety in the city centres of road accidents is resulted. The block diagram of the given system has been received; lacks of the existing position are reflected. The description of necessary actions for creation of methodological base of increase of road safety of traffic in the city centres of road accidents in Byelorussia is performed.

In the article substantive provisions on the road traffic organisation in the city centres the road accidents, which are based on the account of all kinds of losses in road traffic and an estimation of quality of accepted decisions are resulted. Practical, scientific and scientifically-methodical problems on creation the system of safety increase of road traffic are defined.

Keywords: losses in road traffic, methodology of accident forecasting, accident losses, forecasting methods

1. Problem Solving

Works made by the methods of road traffic arrangement on the constant basis are fulfilled just episodically in the Republic of Belarus. As the result together with rather a high rate of auto-mobilization it is a speedy growth of rate of accidents in seats (places) of cities especially [1, 2]. To overcome this situation it is essential to develop scientific-methodical system of traffic safety improvement in accident places in cities, which should be based on the up-to-date methods of accident forecasting and optimisation of the decisions taken.

2. A Structure of Road Safety

A structure of road safety improvement system in cities is on Figure 1.

The whole complex of operations for road traffic safety improvement can be divided into 4 periods:

- obtaining the initial data;
- defining the accident reasons and preliminary decisions producing;
- evaluation of the effectiveness and optimization of the taken decisions;
- measures development and implementation.

The initial data include not only accident statistic, but the other parameters of road traffic in a place that are necessary to forecast the rate of accidents, to calculate the losses and optimise the decisions.

The problem of the initial data obtaining is extremely critical. Present statistics is not suitable for works providing road safety improvement in accident places in cities just because it doesn’t take into account (ignores) the so-called non-registered accidents (all the accidents with material damage and about 17% of accidents with pedestrians that have not lead to serious injures), that makes up more than 90% of all accidents in cities. As regards other initial data, which are necessary for accident forecasting, evaluation of the affectivity and optimisation of the decisions taken, such data are not being defined at all because of lack of their need.

There are unsatisfactory road conditions, vehicle damage, human mistakes (traffic rules violation) among the accident reasons, but there is no any reason concerning road traffic arrangement. It is obvious that defining accident reason by using such initial data and decision-making on the basis of these reasons can’t be optimal.

The evaluation of the complex effectiveness with taking into account the main constituencies of road traffic as it is claimed in the Conception of road traffic safety providing is not being made in the Republic of Belarus [3].

At the best research of accident effectiveness by the statistical method of accident forecasting is being conducted, which is not connected to economy, ecology, sociology, and it is appropriate just to preliminary evaluation during decision-making.

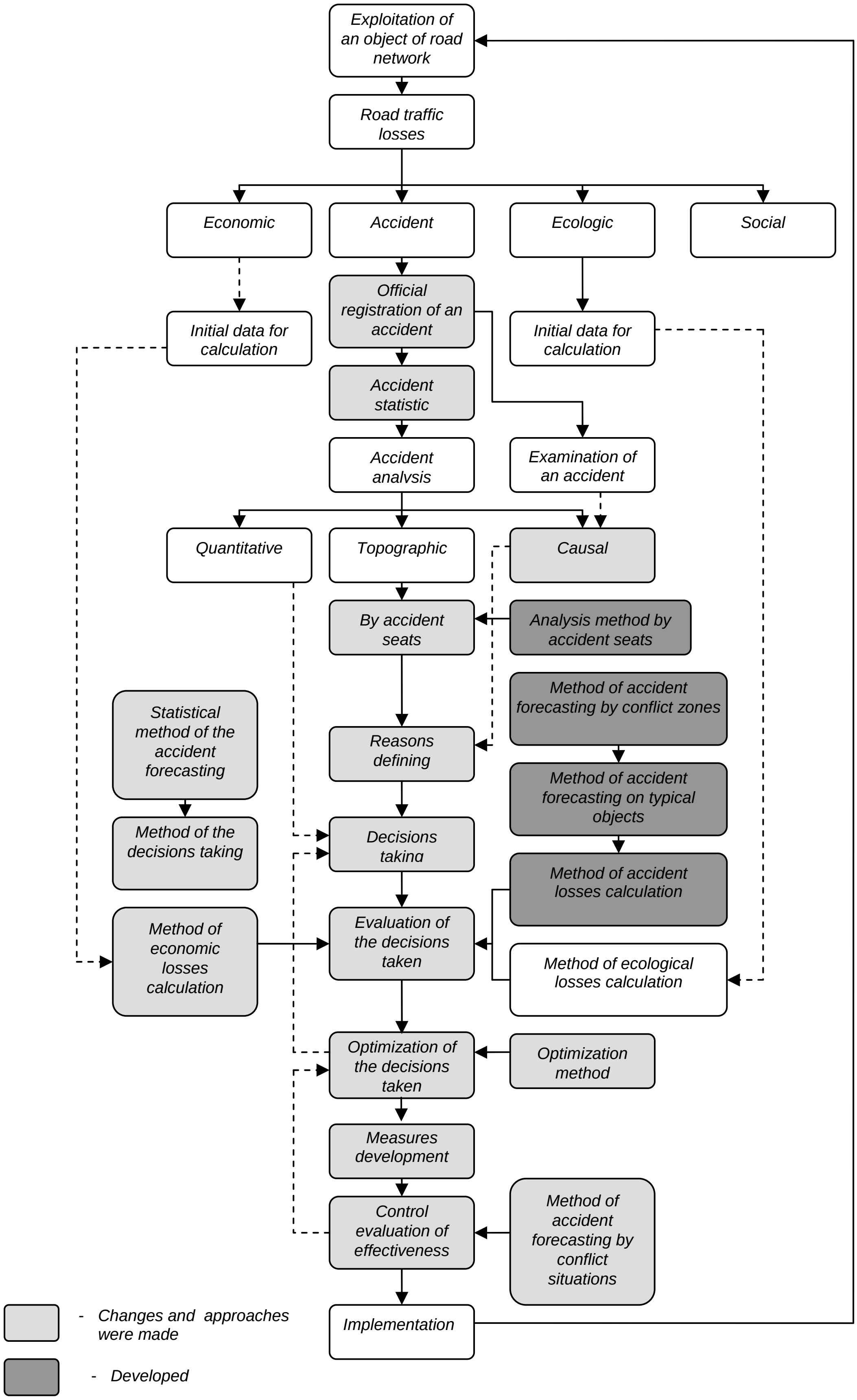


Figure 1. Traffic safety improvement system in accident places in cities

It is obvious that if the taken decisions are not optimal and the decisions do not undergo to evaluation of effectiveness and optimisation, then measures developed on the basis of such decisions can not be optimal. More over the decisions do not undergo the control checking even to define whether they have accident effectiveness.

As the statement indicates on every stage of works there are serious problems and as the result the rate of accident places in cities is unwarranted high.

The term "accident place (seat) in cities" means the place where not less than 3 accidents occur annually [2, 15, 14]. The accident seats in cities include intersections, pedestrian crossings, bus stops, railroad crossings, exits from adjacent territories, places with speed bumps, popular places of crossing violations by pedestrians. Accidents in accident place in cities are the consequences of conflict manoeuvres what is caused by different reasons. The peculiarities of these places are relatively slow traffic speed and large quantity of conflicting members.

The signalised intersections have a special place among accident places in cities as a place of powerful manoeuvred traffic flows. Beside it there is also interaction (crossing) of powerful traffic and pedestrian flows. These interactions are being made in limited area and in limited time, because all flows "compressed" in time since they move not during all traffic light cycle but in limited time of green signal of a traffic light.

As the result, signalised intersections most every have become the main places of the accident, economic and ecological losses. More over signalised intersection define road capacity of streets in cities that leads to appearance of great social losses beside the losses mentioned above. Of course owing to this signalised intersection has become the main object of street road network which indicates the quality of road traffic in cities including safety. That is why signalised intersections have been chosen as the main object to be researched.

The signalised intersections are divided to standard and non-standard conditionally. The standard intersections have 4 or 3 entrance which are directed at a right angle to each other and have one carriageway on each side. Controlling of standard intersections is simpler and depends on movement intensiveness and correlation of transit (direct) and turning traffic flows and on the presence and intensiveness of pedestrian flows.

Non-standard intersections differs from standard by displacement of one or several sides from the centre, by presence of dividing strips, by presence of different from 90° angle of joining, by presence of 5 sides and etc. Non-standard intersections are very individual and they are more difficult to be controlled.

Traffic light controlling at signalised intersections is composed of two main classes – system and local [2, 16, 17, 18]. Local controlling take place at an isolated intersection the controlling of which is not coordinated with controlling at the other intersections. As a rule it is used when intersections are detached from each other (more than 800 m) and the operation of one of them doesn't influent the operations of others. The system's controlling means a coordinated control under several adjacent objects, which are located either along a street (highway) or on several (crossed possibly) streets (network). As a rule, in cities, especially in large, the coordinated control is used.

The structure of traffic light cycle is subdivided into two-phase and poly-phase. The two-phase signalising means that in the first phase all traffic and all pedestrian flows of one of the crossing streets move and in the second phase flows move on the other of the crossing streets.

The peculiarity of poly-phase signalising is that one can single out separate phases for turning flows, pedestrians, traffic flows of every entrance and etc. that allows to create a lot of control combinations taking into account the peculiarities of a separate intersection. Two-phase cycles are simpler, more economic and more ecologic but sometimes they have very dangerous conflicts inside the phase (in-phase), for instance, left-turning traffic flow – opposite transit traffic flow, that is why such cycles are inadmissible by safety conditions. Poly-phase signalising takes off the most dangerous and inadmissible conflicts and it would seem to be safer. But it is not economic, not ecologic and it is often accompanied by overload that causes great quantity of violations (social losses), that causes the accident rate growth.

As it is following from premises, selecting the parameters of traffic light cycle at signalised intersection, especially if it is loaded, is an extra difficult and delicate matter which depends on an engineer's experience and intuition and it is not efficient. Because of absence of workable methods of quality evaluation of road traffic arrangement and optimisation of the taken decisions it is possible to affirm that road traffic arrangement at signalised intersections is far from optimal. Namely, this circumstance is the main reason of inadmissible high losses of every kind including accident losses.

To solve the situation it is essential to do the following:

- to develop the method of accident forecasting on the conflict objects which is useful for obtaining appropriate forecasting by accuracy on both existing object and the stage of designing of an object;
- to develop the methods of accident forecasting for the main typical conflicts: vehicle-vehicle and vehicle – pedestrian that take place at signalised intersections (4 methods);
- to develop the method for accident losses calculation;
- to develop the method of selection and optimisation of the decisions taken on road traffic arrangement on the basis of the developed method of accident losses calculation and existing methods of ecological and economical losses calculation;
- for implementation of the developed methods of accident forecasting and also of methods of accident losses calculation and optimisation the decisions taken to create a complex of computer programs which are available for road traffic engineers;
- for control checking of adequacy of implemented measures effectiveness on the real objects to modify the existing accident forecasting method by making it appropriate for practical use in road traffic engineering.

Speed hump – is a specially organized on the constant basis obstacle for traffic made as jut of the carriage way with radial or trapezoid section which is made of asphalt-concrete or another durable materials and installed across the road (street) without a possibility of driving around which forces the drivers by threat of accident or car breaking to limit velocity distinctly independently on road traffic situations.

Appearance and use of speed humps are connected to great growth of accidents in the second half of previous century that become a national problem for some countries [4, 5, 6]. Especially it concerns on the West-European countries with high population density and specialties of settlements' design with narrow streets of ancient building. Searches of the problem solution, which often have been made on "fresh tracks" and were not fundamental and systematically made, have led to requirements of abrupt reduction of traffic speed. At the beginning it tried to realize by installation of set of traffic signs for speed limitation, however it has not given special effect, because the more limitations were established and the more severe were these limitations, the more drivers broke them. In the different countries the share of infringes was various; however the order of figures remained stable – approximately 75-95 % of drivers broke requirements of abrupt speed limitations.

Then it was started searching and finding ways of compulsory speed limitation. One of them, psychological compulsion, includes the various devices, which create the driver's psychological need to reduce the speed – the effect of narrowing or a curvature of movement trajectory; effect of break of movement trajectory, a special marking, which becomes more frequent; chokers; rumble strips with increasing frequency of sound influence, etc.

The second way is physical compulsion. It includes different kind of devices causing physical need of speed reduction under threat of loss of controllability or breakage of the automobile with an opportunity of accident occurrence. It includes roundabouts with small diameter of central island (or different inside road pavement); physical narrowing or a curvature of a lane by application of protected safety islands for pedestrians with an opportunity of pedestrians movement "on a curve"; an abrupt physical curvature roads ("zigzag", chicane) by application of the ledges protected by an onboard stone; raised above a carriage way pedestrian crossings across a street; cross-section deepening on a surface of carriage way and, at last, prominent obstacles (speed humps) of diversified designs and the sizes [5,6,7,8]. The last appeared the cheapest and easy applicable to various conditions and consequently have become widespread.

It seemed that the decision of a problem of speed reduction has been found at last - cheap, effective, not demanding the control – and in Europe it was started the real boom of speed hump's application. A lot of new modifications have been developed, process of their interaction with traffic was investigated, their efficiency in increasing of traffic safety was advertised, etc. However, there has soon come sobering up – it is appeared that application of speed humps, except for positive influence on traffic safety, also has a wide area of negative influences in the field of economy, ecology and social relations. Application of speed humps conflicts to fundamental tasks of road transport – improvement of quality and reduction of the cost price of transport service, which is based on the balanced ratio of such properties of traffic as safety, profitability, ecological compatibility and influence on society, and not just based on safety as it seemed before. Not having an opportunity to estimate this balanced ratio precisely – as far as it is known (anyway, we did not manage to find), such method of traffic quality estimation in Europe has not been present yet – they have started to limit application of speed humps in "obvious" typical situations. In particular, in many countries, certainly, with different variations, installation of speed humps is forbidden on country roads, in city streets with intensive and moderate movement, on roads with bus movement, in streets with trucks movement, etc. Gradually the scope of speed humps is being narrowed and limited by streets of ancient building, domestic territories, areas of schools, etc. It is considered, that ”speed humps – last tool from a tooling, intended for increase of traffic safety” [9, 10, 11]. Therefore Europeans today search for other, less unhealthy ways of traffic safety increasing, including speed reduction in the necessary places, in the necessary limits and during necessary time, for example, by means of flexible traffic light controlling with the obligatory automatic video control.

In the Republic of Belarus the first speed humps appeared on the beginning of the present century. In some years the great growth of speed humps had began and appropriate organizations has got the planned indicators of installation of speed humps with or without the need. The same practice still has been continuing, unfortunately, sobering has not started. It is necessary to study constantly and to use the foreign experience of speed humps application. However, it should be applied with extra accuracy, taking into account our conditions and features. Also it is necessary to have an effective method of traffic quality evaluation; in particular, evaluation of efficiency of speed humps application that will allow taking more sensible decisions and balancing all basic properties of road traffic. It is necessary also to use available now domestic experience received as a result of application and research of speed humps. Thus one should be guided by positions of ”Concepts of providing of road traffic safety in the Republic of Belarus”, developed according to the Decree of the President of the Republic of Belarus №551 on the 28th of November, 2005 and authorized by the Council of Ministers Decision of the Republic of Belarus on the 14th of June, 2006 № 757 [3].

In the Concept it is pointed out that the road traffic has not one but four main threats (dangers) – accident, ecologic, economic and social. That is why quality improvement of road traffic means reducing of losses of all kinds of dangers, but not reducing of losses of one kind of danger by great increasing dangers of other kinds.

Taking into account the premises it was decided to choose speed humps as a second (after signalised intersection) object for research and to develop a complex evaluating method of evaluation of implementation effectiveness. To achieve these purposes the following tasks must be solved:

- to develop the accident forecasting method on the basis of statistical method for preliminary selection of decisions;
- to develop the accident forecasting method on the basis of conflict zones method for accident effectiveness evaluation and optimisation of the decisions taken;
- to develop the method of accident, economic, ecologic losses calculation for evaluation of social-economic effectiveness and optimisation of the decisions taken.;

Thus, the researches undertaken are based on the main objects of conflict interaction of traffic flows and traffic-pedestrian flows.

3. Methodology of the Road Traffic Engineering

The main methodical clauses of road traffic engineering in accident places of cities in the Republic of Belarus must include the following items: terminology, methodology and ideology, technology, norms, structure, control and financing. Let’s consider all these items.

The special terms that are used in road traffic system, in particular, in subsystem of road traffic arrangement must be developed, coordinated and approved. Here the international coordination must be fulfilled. The approximate quantity of unified terms is not less than 500.

Methodology of road traffic must be based on the following aspects:

1. Initial data defining for evaluation of road traffic quality on the basis of the methods which are developed and proved by established order.
2. Calculation of all kinds of losses (including social).
3. Analysis of sources of losses in road traffic of higher level.
4. Evaluation of road traffic quality and its constituents by the losses rate.
5. Optimisation of all managing supposed impacts by the minimization criterion.
6. Development of operative measures for the road traffic arrangement.
7. Optimisation by the minimization criterion of losses of possible impacts on the road traffic process.
8. Development of prospect measures for the road traffic arrangement.
9. Development of propositions for the norm correction (traffic lows and norm of a direct impact – traffic rules).

For efficient implementation of all clauses of the road traffic safety system in accident places in cities the ideology must be developed, which should include the main purposes and tasks, role and place of the ”Road traffic arrangement” item in the road traffic system; the main road traffic arrangement principle and the chapter “Responsibility” of course.

There are the basic clauses of Technology of road traffic arrangement developed in BNTU. The technology includes collecting and processing of the information concerning quality (characteristics) of road traffic and its constituents; evaluation of present road traffic arrangement quality; analysis of present state of accident places; the methodical aid of operative measures implementation; the methodical aid of prospect measures implementation; and also the clause concerning the control under fulfilment of managing decisions. All norms in road traffic arrangement must be ordered. That is why it is necessary to develop the hierarchy of norms in road traffic arrangement system where juridical norms, methodical norms, technical norms responsibility and the rules of their change must be clearly defined. Also it is necessary to develop Guidance for the road traffic arrangement in cities – the main unitary methodological document concerning road traffic arrangement.

The structure of managing in the system of road traffic arrangement can be simply represented by the following way (Fig.2).

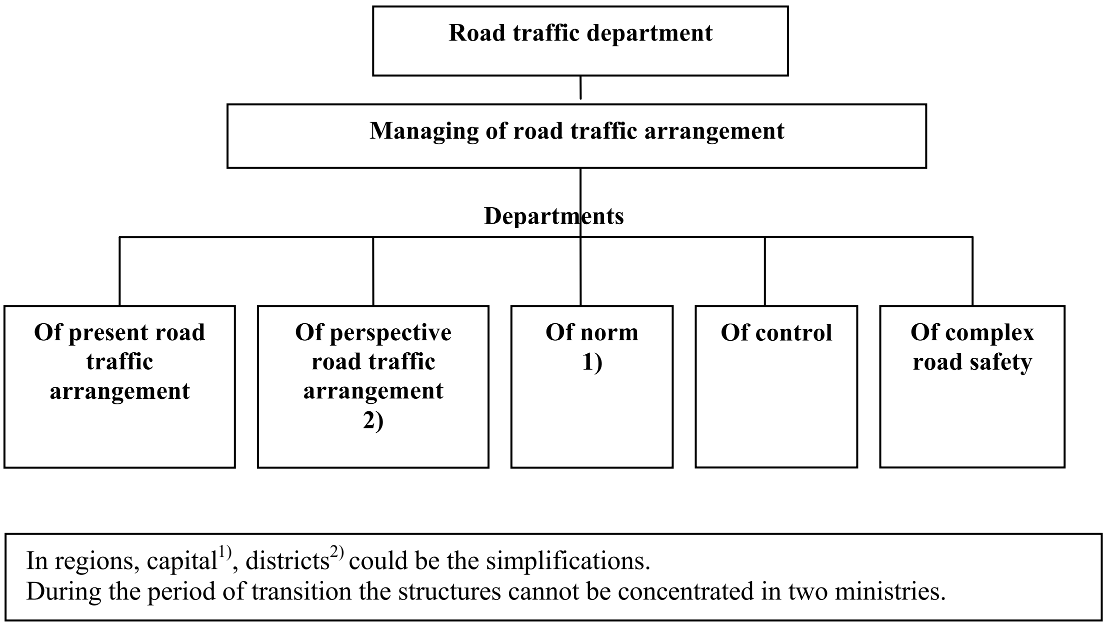


Figure 2. Structure of managing of road traffic arrangement

The control in road traffic can be represented by the following way.

$$\left.\begin{array}{l}\text{over the condition of road traffic arrangement - d + s}\\ \text{over directions implementation - s + d}\\ \text{over designing condition - d + s}\\ \text{over scientific researches - d + s}\\ \text{over training of specialists - d + s}\end{array}\right\}\text{- p}$$

where d – departmental, s – state, p – public

Financing in the system of road traffic arrangement can be both state-financed (as the main on the first stage) and at the expense of other incomes. Here it is necessary to provide the system of encouragement at the cost of reducing of accident, economic, ecological and social losses. A part of finances stays among people, a part can be used for the development of road traffic arrangement and a part is used for the encouragement of specialists worked on road traffic arrangement. Here part and correlation of the effect of losses reduction can be changed while trends are discovered. The return of the effect in state use is possible by enlarging the taxes for road vehicles, increasing the part of contributions of compulsory insurance, increasing fuel price, increasing transit payment (in central parts of cities, within a parking and so on), increasing of ecological tax and etc.

4. Conclusions

Thus, to solve these problems and to develop useful scientific-methodic system of traffic safety improvement it is essential to solve a set of practical, scientific and scientific-methodical tasks. Among them there are:

- to make compulsory statistical reporting about all accidents including accidents without injured;
- to give to accident seat (place) appropriate status which would claim reviewed reporting, evaluation of effectiveness, optimisation of the decisions and measures implementation;
- to develop the method of accident place analysis;
- to adapt the statistical accident forecasting method to conditions of the Republic of Belarus in usage of speed humps;
- to develop the method of accident forecasting by potential danger of higher precision which could be used for practical implementation for effectiveness evaluation and optimization of the decisions taken for both existing and being designed conflict objects (conflict zone method);
- to develop the methods of accident forecasting by the method of conflict zones for speed humps and four typical conflicts at the signalised intersections: vehicle-vehicle (side impact, turning, head on impact, impacts in one directions), vehicle-vehicle (rear-end accidents), vehicle-pedestrian (transit vehicle-pedestrian) and vehicle-pedestrian (turning vehicle – pedestrian);
- to develop a section of the methodical aid for accident losses calculation concerning specific cost of accident of different consequences' weight;
- to develop the method of economic losses calculation for speed humps;
- to develop the method of optimisation of the decisions taken concerning road traffic safety increasing by the road traffic arrangement methods at signalised intersections, controlled pedestrian crossings and speed humps;
- to perfect the accident forecasting method for conflict situations with purpose to increase forecast precision for control evaluation of accident effectiveness measures during their implementation;
- to develop the method of control evaluation of accident effectiveness measures during their implementation;
- to develop the program package for accident forecasting, evaluation of effectiveness and optimisation of the decisions taken with purpose to implement the system of road traffic safety improvement developed;
- to develop propositions for perfection of norm base in road traffic.

References

1. Analytical collection: The Information about the State of Road Traffic in Accident Rate in the Republic of Belarus in 2008. Minsk, MIA of Republic of Belarus, 2009. (In Russian)
2. Vrubel, Y. *The Loss of Determination in Road Traffic / Ed.by Y.Vrubel, D. Kapsij, E. Kot.* Minsk: BNTU, 2006. 252 p. (In Russian)
3. The Conception of Road Traffic Safety Guarding in the Republic of Belarus, the Republic of Belarus Council of Ministers Decision on the 14 th of June, 2006, Nr.757.
4. Griffith, Michael S. Safety Evaluation of Rolled-In Continuous Shoulder Rumble Strips Installed on Freeways /Ed. by S. Griffith Michael. Statistical Methods in Transportation and Safety Data Analysis for Highway Geometry, Design, and Operations, *Transportation Research Record,* No 1665, October 1999. pp. 28-34.
5. Moeur, R. Analysis of Gap Patterns in Longitudinal Rumble Strips to Accommodate Bicycle Travel /Ed. by R. Moeur. Pedestrian and Bicycle Transportation Research, *Transportation Research Record*, No 1705, 2000, pp. 93-98.

6. Speed humps [Electronic resource]. – Mode of access: http://www.mn-traffic-calming.org/cgi-bin/search.cgi?by_device=1;device=4. – Date of access: 16.03.2009.
7. Compton Speed Bumps [Electronic resource]. – Mode of access: – http://library.wustl.edu/units/spec/archives/facts/compton_bumps.html. – Date of access: 16.03.2009.
8. Traffic Calming Protocal Manual [Electronic resource] / DOWL Engineers 4040 B Street Anchorage. – Alaska, March 2001. – Mode of access: – http://www.ci.anchorage.ak.us/iceimages/traffic/trafcalm.pdf
9. PIARC: XXth World Road Congress. Montreal, 3–9 September / *Transportation and Urban Space Planning / National Reports*. 20.22.E – 1995, 487 p., PIARC: Urban road design and architecture / Reference: 10.08.B, Routes/Roads special issue II-1995. p. 51-126.
10. Ewing, R. *Pedestrian and transit friendly design. Joint Center for Environmental and Urban Problems / Ed. by R. Ewing.* Florida Atlantic University/Florida International University, March 1996. 103 p.
11. PIARC: Reduction of car traffic in city centers. Reference: 10.01. B, Routes/ Roads 1990, p. 1–48, 181. PIARC: XX th World Road Congress. Montreal, 3–9 September / *Transportation and Urban Space Planning / National Reports.* 20.22.E. 1995. 487 p.
12. *Urban Street Geometric Design Handbook.* Washington: Institute of Transportation Engineers, 2008. 460 p.
13. *Transportation Impact Analyses for Site Development: An ITE Proposed Recommended Practice*. Washington: Institute of Transportation Engineers. 2006. 140 p.
14. Island-wide Traffic Calming programs status report [Electronic resource]. – Mode of access: http://www.co.honolulu.hi.us/dts/tcalming.pdf. – Date of access: 16.03.2009.
15. Pande, A. Assessment of freeway traffic parameters leading to lane-change related collisions / Ed. by A. Pande, M. Abdel-Aty, *Accid. Anal. Prev.,* Vol. 38, 2006, pp. 936-948.
16. *Highway Capacity Manual*. TRB. Washington, DC, 2004. 1134 p.
17. Powell, T. *The Transport System: Markets, Models and Policies / Ed. by T. Powell*. PTRC Education and Research Services, Ltd., 2001. 302 p.
18. Teply, S. *Second Edition of the Canadian Capacity Guide for Signalized Intersection / Ed. by S. Teply, D. Allingham.* Canada: Institute of Transportation Engineers, 1995. 115 p.

Transport and Telecommunication, 2009, Volume 10, No 1, 38–47
Transport and Telecommunication Institute, Lomonosova 1, Riga, LV-1019, Latvia

PROBLEM OF MATHEMATICAL INSTRUMENT SELECTION FOR THE PURPOSE OF INVESTIGATION OF EXHAUST GASES DYNAMICS IN URBAN AIR

Stanislav Grishin

Transport and Telecommunication Institute
Lomonosova Str.1, Riga, LV-1019, Latvia
E-mail: ctac@tsi.lv

This work, by making specific references to investigation of ecological problems shows the legitimacy of two approaches: the apparatus of the theory of chance and mathematical statistics and the conceptually alternative approach connected with using the apparatus of the theory of differential equations in partial derivatives and equations of mathematical physics. The investigation comes to the conclusion that the second approach manages to penetrate deeper into the physical essence of the examined phenomena and yielding analytical results directly connected with the physical aspect of a particular process. Investigators face the prospects of receiving precise or approximate results with respect to the process in its dynamic development; they also get the possibility of forecasting the course of a particular physical phenomenon without the necessity of collecting a huge volume of statistical data. The second approach is deeper and more comprehensive – for example, if problems of motor traffic ecology are to be solved. On the other hand, the expediency of using approaches of the theory of chance and mathematical statistics is not argued. The two approaches, not conflicting with each other, are useful and mutually complementary. The task of the author was to show the legitimacy and the advantages of using a powerful apparatus of mathematical physics in cases where only the apparatus of probabilistic approaches is currently used as a rule.

Keywords: anthropogenic pollutions, exhaust gases, mathematical statistics, dynamics, partial differential equations, mathematical physics equations

1. Introduction

As a result of people’s economic and engineering activities, large volumes of chemicals being in gas and aerosol state are injected into the atmosphere. On getting to the atmosphere, these substances are subject to a number of physical and chemical changes. All of those mechanisms are interconnected, each of them being a part of the overall complex problem of atmospheric disperse systems related to environmental protection.

The bulk of the modern tasks of the dynamics and kinetics of atmospheric disperse systems are described by multivariate non-linear equations in partial derivatives, and the solution of tasks of that class may be found only approximately – through approximation of the initial differential problem by finite-dimensional model. At that, the proof of the convergence of the approximate solution to the one of the initial differential model is quite difficult and even impossible in many cases. Therefore, it is extremely important to investigate the issue of a simplification of the initial complicated mathematical model – so that the received task would imply, first of all, an analytical and numerical solution and, secondly, would preserve the basic properties of the initial full mathematical model (the energy and mass conservation law and other fundamental laws).

City atmosphere is a complicated dynamic system implying various physical and chemical processes running; their intensity depends on specific features of the city in question. To describe these complicated atmospheric eddy processes, a complex mathematical model can be developed, allowing one to solve a broad spectrum of problems in the environmental protection field. Such a model contains the following:

1) the model of hydro-thermodynamics of urban and/or regional atmospheric eddy processes;
2) the models taking into account kinetic processes of nucleation, condensation, and coagulation, as well as mass exchange processes at the gas-particle phase;
3) the gas-borne particles (and aerosols) transfer and diffusion equations in city and/or region atmosphere, taking into consideration the photochemical and other transformations.

For example, the model of photochemical transformation should take into account man-made emissions with respect to substances typical to large industrial cities and regions; furthermore, the space-time dynamics of environmental attributes, brought about by the secondary photochemical pollution, should be investigated. As regards kinetic models of condensation, fluctuating nucleation processes and progressive growth of particles in saturated environment should be investigated, resulting in the birth and the subsequent development of disperse phase, and contamination of the environment.

In general, the methodology of investigating the urban ecologic problems looks as follows:

- formalization of concepts “environment”, “environmental quality” and similar concepts related to the specific application domain;
- formulating environmental health criteria;
- revelation, refinement, and investigation of the main factors affecting health of urban population from ecological standpoint;
- development of methods of monitoring and full assessment of environmental quality;
- development of a substantiated scientific concept of urban environment quality control and a possibility of short-term or long-term forecast.

A peculiar feature of ecology-related problems is, first of all, an extreme uncertainty of the problem statement; another feature is the complex nature of tasks implying the necessity of taking into account the above-mentioned miscellaneous factors, ranging from geology to the alert level. According to engineering practice, the computation error may come up to hundreds of percent in this case. The purpose of applying formalized methods in ecologic design, mathematical modelling and forecasting is a more precise calculation of environmental damage volume, the forthcoming costs, and the evaluation of effectiveness of the respective measures applied.

This work investigates the choice of apparatuses for developing the model, as a tool of investigation of the urban atmosphere contamination from transportation vehicles. Some investigation tools applying methods of theory of chance and mathematical statistics are examined along with some models of the classic apparatus of differential equations in fraction derivatives and the powerful apparatus of mathematical physics.

2. Ecological Monitoring of Urban Environment Quality and Its Hypersensitivity to Measurement Error

Using the apparatus of mathematical statistics (and some other mathematical apparatuses implying model development based on results of one-time and integral measurements of environmental quality – in particular, that of urban outdoor air) to determine the dynamics of exhaust gases concentration in urban outdoor air – is related to the problem of accuracy of measurement. Namely, single-shot accuracy is quite low with respect to measurements of emission concentration in urban outside air. Even if we increase accuracy by increasing test frequency to any extent as high as possible – we will nevertheless be able to assess the condition of urban outside air after single shots – especially under dynamic urban conditions. Therefore, neither should we be satisfied by accuracy of integral criteria, indices, and indicators to assess the quality of urban outside air. Besides, it is quite impossible to install instrumentation at each point of the city. That’s why we have to restore the general picture of outside air contamination according to measurement results from separate points – with the help of the so-called interpolation models. So far, such interpolation models have not been developed to the extent allowing their wide usage in practice. Therefore, to apply the mathematical statistics apparatus for outside air monitoring, the outside air quality automatic control points should be developed, supplementing them subsequently with mobile inspection tools. It is quite important to note that interpolation methods of modelling are quite acceptable in compact homogenous mediums – like, for instance, in fixed water column. As regards urban conditions that may imply various heterogeneities of the terrain between two points of atmospheric measurements – a “blind” mechanical application of interpolation methods may yield absurd results. For this reason, interpolation methods taking into account heterogeneity of terrain and the existence of intermediate emission sources – are absent. It is exactly the above-mentioned aspect, along with the impossibility of a quick measurement of hundreds of foreign matters in outside air, – plus the impossibility to interpret the results of measurement – urge ecology experts to develop some more general methods of environmental quality assessment. Therefore, to be able to use a statistic model steadily, one has to test them by statistically valid methods. However, there is no time to do it as a rule, since an incredibly large number of measurements would have to be processed a few times during the day – with uncontrolled errors (the so-called “white noise”). Moreover, such statistical tests would have been too costly from economic standpoint.

Since single-shots of foreign particle concentration measurement in urban outside air feature low accuracy – we will, first of all, make the very concept “air quality measurement” somewhat more precise in terms of the language of theory of sets – before we substantiate this fact. Measurement is single-valued transformation of a set of objects into a set of results, – retaining the relations existing on the set of objects. Measurement is a process of obtaining the value of measured quantity and comparing it to another quantity – conventional as a unit of measurement. Measurement as such is an integral part of control of any process or object. Since control is a directed impact of a controlling object upon a controlled one – we cannot assess the results of control without the knowledge of numerical characteristics of an object or process received by way of measurements. Normally, the quality of outside air, aquatic resources and soil, as well as environmental release from enterprises, the level of noise, irradiation and other physical factors – are chosen as measuring objects in urban environment. If we represent urban outside air as a homogenous innocuous environment containing foreign substances harmful to people – we will consider the unit of measurement as the volume of the foreign particle content with respect to a unit volume or unit weight, which is normally called emission concentration. In practice, this is expressed by mg/m^3 in the air, mg/l in water m and mg/kg in soil. If airborne emission or discharges to water are measured, the units of measurement will be g/c or t/year. According to [1, 2], one-time concentration is determined as the 20-minute averaging of instantaneous values of concentration with respect to the given kind of extraneous substance in outside air. At that, mean daily concentration is determined as the average concentration with respect to one-time values revealed during the day. Mean monthly concentration is determined as the average value of mean daily concentrations. Mean year concentration is the average of mean monthly concentrations. Background concentration in the given region is concentration of substances in air or water, determined by the global and the regional sum of natural and anthropogenic processes. All the units of measurement described above are called weight units. As a unit of measurement, just the number of contaminants is frequently used – i.e., the number of particles (moles) of the contaminant with respect to a million or a billion of air particles (ppm-part per million or, ppb-ppp-part per billion). For instance, under the air temperature $0^\circ C$ and $25^\circ C$ the correlations between units of measurements of concentration – mg/m3 and ppb with respect to some widely spread harmful contaminants polluting atmosphere are shown below in Table 1:

Table 1. Correlations between units of measurement of concentration of some harmful substances under temperature *0ºC* and *25 C*.

Substance	CO	NO	NO_2	SO_2	O_3
ppb	1	1	1	1	1
Mg/ m^3 $0^\circ C$	1.25	1.34	2.05	2.86	2.14
Mg/ m^3 $25^\circ C$	1.15	1.23	1.88	2.62	1.96

In general, the diversity of units of measurement of urban air quality is far less than that used with respect to aquatic medium and urban air. The main reason is a less developed state of exploration of the problem.

3. Accuracy of Measurement of Urban Outside Air Quality

Now we will consider some issues of urban outside air quality and increased sensitivity of statistic models used for determination of exhaust gases by the method of ecological monitoring. To do this, we will evaluate the accuracy of measurement by the example of a single substance – for example, nitrogen monoxide – at one point of urban outside air only. Let's consider a very simple method of measurement as follows: 1 m^3 of outside air is sampled into any enclosed space with a variable orifice – like a cylinder with a piston and variable orifice. Then, by squeezing out air from the cylinder – molecule after molecule – the pollution agent molecules, present in the air, are counted (in our example, the agent is nitrogen monoxide). The accuracy of this, purely theoretical method, is absolute – there is no error whatever. However, when this theoretical method is applied in actual practice – the observer, as a rule, is moving from the object and a relative reduction of object, as well as an increase of its motion speed and reduction of its life span take place – along with some other similar changes. Under these circumstances, the confidence in display of all calculated molecules of the pollution agent (i.e., the precise identification of the object type) - decreases. This means that a few molecules of nitrogen monoxide may be omitted by taking them for other molecules. For example, 5 out of 100 may be omitted, or, 105 may be calculated instead of 100. Therefore, when an in-situ measurement takes place, we can speak not about the absolute precision of the quantity measured, but only of the absolute error $\Delta R = R_{exact} - R_{real}$ of measurement of the value investigated, or its ratio error $\Delta R(\%) = \frac{R_{exact} - R_{real}}{R_{real}} \cdot 100(\%)$ where R_{exact} is the precise (ideal) meaning of the quantity measured, whereas R_{real} is the measurement result [3, 4]. Obviously, to increase the measurement accuracy, a few samples of 1 m^3 may be taken right away, measuring each of them subsequently. As a result, we will have a set of numbers with certain regularity embodying a single number, which is a precise (ideal) value of the quantity measured. As we know from the course of the theory of chance and mathematical statistics, this ideal and true value of the quantity measured (the concentration of nitrogen monoxide in 1 m^3 in this case) is for some objective physical reasons – a random variable that may be calculated based on results of separate measurements, with some likelihood ratio. In the specific case of ours, the error of one-time measurement of monoxide nitrogen concentration depends on a number of reasons of methodical, instrumental, and subjective nature: systematic errors occurs as a result of mistakes in measurement technique; instrumental errors are a consequence of inaccuracy of gauges and instrumentation, while individual errors are those made by experimentalist observer. According to engineering experience to date, errors of single shot-based measurements in gas dynamics and hydrodynamics come up to dozens of per cent. As it is known from the course of the theory of chance, in order to calculate the value of a random variable, one has to know its distribution function – i.e., the one showing the probability of the random variable assumes particular numeric values. This, in its turn, is defined by physical properties of the processes of foreign matters distribution in the environment – air, water, soil. As regards the processes of distribution of substances in the environment, they are described by fundamental laws of physics and chemistry, expressed in mathematical terms only – i.e. by correlations, equations, and models of mathematical physics. Therefore, in order to develop some more adequate, efficient, and universal models for determining concentration of various foreign substances in the environment (air, water, soil) by applying methods of theory of chance and mathematical statistics – one has to take into account the laws of environmental distribution of substances. At that, the turbulence of atmosphere by physical properties of the very environment etc. should also be taken into account; in other words, to develop adequate models of solution of the problem examined, the powerful apparatus of mathematical physics should also be used along with methods based on statistical distribution.

According to observational experience generalized in literature, random values of emission concentration in atmosphere and water comply with the Gaussian law. As we know, the values of random variables X, characterized by the Gaussian law $\rho(x) = \frac{1}{\sigma \cdot \sqrt{2 \cdot \pi}} \cdot e^{-\frac{(x-m)^2}{2 \cdot \sigma^2}}$ are determined by mathematical expectation $m = M\{X\}$ and the variance (dispersion) $\sigma^2 = D\{X\}$ [3,4]. Moreover, arithmetic mean set derived from n of measured values may also be used as the measured quantity value – provided the number of measurements is sufficiently large. At that, the accuracy of the mean derived from n measurements of the value complying with the Gaussian law is by $\sqrt{n}$ times higher than the accuracy of single measurement. As a rule [2], the relative net inaccuracy of measurement of mass concentration in outside air should not exceed $\pm 25\%$ Therefore a single measurement of the extraneous substance concentration in outside air features quite a low accuracy. Even if we increase accuracy by taking a few samples, we will nevertheless be unable to judge on the condition of outside air after single measurements – especially in urban conditions. Experiments show that cities populated by 1-1, 5 million inhabitants feature daily fluctuations of extraneous substances concentration in central parts of the city (2-3 times). Taking this fact into consideration, let's get back to the considered example of determining the nitrogen monoxide concentration at one point of town: we will try to determine the daily mean concentration of nitrogen monoxide at one point of town. Let's assume that the measurement takes place 3 times a day. If extraneous substance concentration values change by 2 times daily, the maximum error of a single measurement will be equal to 100% at the absolute instrumental accuracy. Then, the pooled error of the three measurements will be $\frac{100}{\sqrt{3}}\% \approx 57.8\%$. Consequently, in order to measure the daily mean concentration of extraneous substances in outside air downtown with the required accuracy (for instance, it makes $\pm 25\%$ according to National Standard – see [5], – at least 16 measurements should be performed, each time with absolute precision. If the one-time measurement error is $\pm 20\%$ which is considered quite acceptable with respect to modern instrumentation – the necessary number of measurements to determine the daily mean concentration of extraneous substances in the downtown outside air with the required accuracy $\pm 25\%$ – will be at least 24. In other words, measurements should be performed hourly. It should be noted however that, if we manage to know the long-standing average daily curve of extraneous substance concentration values at each point of the city – the number of measurements in these specific city points can be slightly decreased. The process of measuring daily mean concentration of the main extraneous substances (CO, NO, NO_2, SO_2 и O_3) by automatic instrumentation, currently applied in most of European cities, is based on even more complicated methods to achieve the accuracy needed. The impossibility of a quick and urgent measurement of extraneous substances in natural environment – in particular, in urban outside air, – and the impossibility of the adequate interpretation of measurement results made experts look for some more general ways of environment quality assessment[6]. By this time, these works are at the stage of investigation, and so far, experts have used to manage just by concentration meanings of up to ten extraneous substances in air, water, and soil.

If just one concentration meaning could have been chosen as an environmental criterion (for instance, only nitrogen monoxide concentration as air quality criterion, bromine concentration – as water quality criterion, and lead volume as soil quality criterion – it would have been simple enough to solve the problem of measurement and regulatory actions for environmental quality. However, the environment contains a lot of substances extremely harmful to human's health if their concentration is high. Even if we assume that we have managed to measure concentration of each of them in the environment – it would be practically impossible anyway to make the general assessment of the environment condition. That's why scientists and ecology experts are facing the tasks of developing some general integral estimations of environmental quality. The above-stated information on the accuracy of measurement of environmental quality allows us to pass over to a brief discussion of integral criteria, integral indices, and integral indicators to assess the environmental quality. When the influence of various airborne harmful substances on human health is investigated, the notion of Maximum Permissible Concentration (MPC) is normally introduced and included into the respective sanitary standards. MPC is the maximum concentration of an extraneous substance in natural environment, attributed to a definite average time. This concentration, influencing a human either periodically or throughout the human's life, does not exercise any harmful influence upon the human and the environment in general (neither does it cause any long-term effects). The MPC notion includes the maximum one-time MPC and the maximum average daily MPC. The maximum one-time MPC is set to preclude any reflect responses from humans, while the average daily MPC is determined as the pollutant concentration in the air not rendering any harmful effect upon humans inhaling the air round-the-clock. Finally, we remind that the maximum permissible concentrations are determined as a result of medical investigations and are approved by the respective public health authorities [7]. Currently the total number of rated concentrations in water, soil, and air has been set with respect to 8 000 substances worldwide.

Any integral estimation of environmental quality is essentially a convolution of a set of measurement results, performed at the intuitive and the formal level. In terms of mathematical statistics, numeric or graphic convolution is construed as any convolution of information extracted from a data file to reveal at least one of its inherent features. Academician N.N.Moiseev in his works dedicated to simulation of natural economic systems (the 70-ies of the XX century) had developed mathematical models of determination of environmental status indicator. These models have won international acclaim. Currently they are used actively both in Russia and the majority of European countries. These models form a basis for many technical measuring systems currently used to determine the environmental quality – in particular, that of urban outside air. Before these works by N.N. Moiseev were published, the following integral estimation of environmental quality had been used with respect to the environment containing a few contaminants with synergistic effect:

$$I_n = \sum_{i=1}^{n} \frac{C_i}{\mathrm{MAC}_i}, \tag{1}$$

where C_i is the concentration of i-th contaminant, while MAC_i is maximum allowable concentration of i-th substance.

Practical application of this estimate is quite difficult since, if the estimate is to meet the accuracy requirements similar to those posed to its components, - the frequency and the accuracy of one-time measurements will go beyond technically feasible parameters at $n > 3$ already. To get convinced in the fact, we will consider the example as follows: let's assume we deal with three kinds of gaseous impurities in outside air, that is to say, $n = 3$. Then,

$$I_n = \frac{C_1}{\mathrm{MAC}_1} + \frac{C_2}{\mathrm{MAC}_2} + \frac{C_3}{\mathrm{MAC}_3}. \tag{2}$$

Since all the three random variables in (2) are independent, the common error is formed by three errors of individual values. If the common error of computation should not exceed 20%, the computation error when calculating the meaning of one value should not exceed 65%. This means that calculations are to be performed every 4,2 min. which is impossible under the current technical conditions of many developing countries. Here we will note that measurements are fixed each 3 minutes in Berlin, allowing one to achieve the measuring accuracy of 54% and use the simplest methods of integration of separate indices. At the current level of instrumentation and measuring techniques even simple and easily interpreted indices yield the necessary accuracy only for average annual values. Accuracy issues are a stumbling block actually for all indicators of environmental quality; however, this does not hamper scientists and ecology experts to continue their development. Now, we will formulate the conditions at which convolution may serve as indication:

- indication should guarantee sensitivity of meanings of received values to be able to trace the space-time variability of the variability related to the process of determining factors. Otherwise it should allow to prove that no changes have taken place;
- indication should be developed so that any observation might be admitted to take part in it;
- indication should be expressed so that at least some of the people interested in the subject might be able to understand its interpretation;
- indication should provide for the possibility of receiving the estimate for the entire city, according to estimates of its part or objects;
- indication should represent values and numbers, mathematical operations, with which they are stated at least in one of natural spaces.

The bulk of well-known indicators have been developed for natural ecological systems. Indicators are subdivided into marker indicators and analytical indices, which, in their turn, are subdivided into conventional functionals and desirability functions [6]. It is important to note that a city essentially differs from a natural ecosystem, the main differences being as follows:

- contamination of natural territory, outside air, surface waters is a lot more intensive and inhomogeneous with respect to extent area than the one typical to natural ecosystems;
- the time history of contamination level of outside air within the daytime (the so-called diurnal course) is by hundred times more intensive than the one in nature;
- the number of harmful impurities makes dozens – unlike units in nature;
- the dynamics and the location of emission points are changing faster than in natural ecosystems.

The environmental quality control in cities, unlike natural complexes, imply taking control decisions within days, and control actions – within the month's time. In Berlin, for instance, at elevated concentration of ozone in outside air person drivers are recommended to limit the traffic in town. Scientific approach to quality control implies choosing the time, directions, and the term of control actions based on regular measurements and forecasts of ecological situation development. The above-stated quality indices are not applicable for day-to-day management of urban environment for the following reasons:

- low accuracy or achieving a high accuracy too long;
- Inadaptability for ecologic conditions.

However, the above-stated does not mean that indicators can not be applied in a city at all. Just like in natural eco-systems, they can be used to measure processes lasting for years, and to control these processes – for instance, construction and reconstruction of highway systems, construction of purification works. For this purpose, well-known indicators should be adapted to urban conditions and, possibly, a number of special models describing load exercised on urban territories, public health, and similar factors.

4. Extrapolative Models

Extrapolative models development technique is as follows: characteristics of the main emission points are described for urban outside air; the urban landscape, the site development parameters and the meteorological situation are described; then concentrations of contaminating impurities are calculated at each point, and areas subject to contamination are calculated.

Extrapolative models imply that scattering calculation from point sources are developed on the basis of one of fundamental laws of physics – balance equations. The essence of a balance equation can be illustrated by a simple example as follows: let's assume that a source of the substance with specific concentration $C_{unit\ conc.}$ and the inflow rate $\vartheta_{\text{inflow}}$ is located inside a volume V having the surface $S = \partial V$. Let us set the normal motion speed of the substance towards the surface S by $\vartheta_{\text{movement}}$, the volume element – by dV, and the surface element – by dS. Then the scattering process is described by the equation as follows [8].

$$\int_V \frac{\partial\left\{\rho \cdot C_{unit\ conc.}\right\}}{\partial t} dV = \oint_S \rho \cdot \vartheta_{\text{movement}} dS + \int_V \vartheta_{\text{inflow}} \cdot C_{unit\ conc.} dV, \tag{3}$$

where ρ denotes specific gravity of the substance investigated.

In (3), the volume integral in the left hand side of the equation denotes the changing speed of the quantity of investigated substance in the given volume; the surface integral in the right hand side of the equation is the complete flow of the substance through the surface S, while the volume integral in the right hand side (3) describes the influx of the substance in the volume V.

Some transformations can be made with the balance equation (3) – to take the actual urban conditions into account. For example, we may set up various speeds of transfer along different directions, simulating the terrain; we can enter various kinds of roughness factors of geological substrate etc. It should be noted that direct computation of integrals is very cumbersome and, therefore, various numerical models are applied in practice. At that, accuracy of all types of models is defined by the scale and the precision of description of reference and boundary conditions. A higher accuracy may be achieved through macro scale–based models. In this case, a smooth and even surface is examined, as it were, and the sole emission source is located at high altitude – so high that surface roughness can be neglected. The model will be simple and not completely inadequate, but its computational accuracy will be high. If we consider a town where the emission source is located at a low altitude – we have to take into account the turbulence occurring in street canyons, around buildings, and in natural depth shapes. Then the model will be getting more complicated and its adequacy will increase with respect to actual process of transfer of contaminants, – but its computational accuracy will drop.

At present, the most well-known probabilistic statistical methods of calculating the expansion of extraneous substances in urban outside air are models based on normal distribution of random variables [5]. Many experiments show that these models can be used only to assess the maximum possible overland concentration of impurities at the worst dispersion conditions. For terrain records, vertical temperature profile, and other weather conditions some more complicated models are worked out – like hydro-thermodynamic model. However, as far as the latter is concerned, its adequacy with respect to actual contamination areas remains doubtful under the conditions of urban high-density zone and complicated micro-meteorology.

5. Interpolation Models

Interpolation models development technique is as follows: contaminating impurities concentration levels in the air are measured at some city points by stationary automatic recording stations. Afterwards, the impurity concentration levels are calculated at some points located between each two adjacent stations, taking into account the urban landscape and weather conditions. As it was stated above, interpolation models use actual values of impurities concentration at given points as baseline data. Impurities concentration values between given points are calculated according to interpolation formulas (that's why the models are called "interpolation models" [9]); as a rule, linear interpolation is used of the kind as follows:

$$F(n+x) = \frac{L-x}{L} \cdot F(n) + \frac{x}{L} \cdot F(n+L),\ x \in [0, L],\ n = \overline{1, N}, \tag{4}$$

where $F(i)$ is the value of interpolating function into the function value at i -th point, L is the distance between datum points, while N is the general number of points at which impurity concentration values on air were measured by stationary automatic stations.

It is obvious that, at linear interpolation of the kind (4), the mean square deviation will be:

$$ERROR = \frac{x}{L} \cdot \Delta(n, L-x) + \frac{L-x}{L} \cdot \Delta(n, x) - \frac{x \cdot (L-x)}{L^2} \cdot \Delta(n, L),$$

where

$$\Delta(n,\bullet) \stackrel{def}{\equiv} \{F(n) - F(n+\bullet)\}^2 .$$

As it was mentioned in the introduction, interpolation methods of modelling are more or less acceptable with respect to homogenous environment – like for example, still water column. In a city where some variegated irregularity of terrain may be located between two measuring points, a "blind" mechanical use of interpolation methods may yield absurd results. For that reason, interpolation methods taking into account terrain irregularity and the existence of intermediate emission sources – are missing.

Summing up we can say that, to be able to use one or another probabilistic statistic model with assurance, they should be subject to a compulsory statistically valid testing. As a rule, there is lack of time to do it since it is necessary to process an incredibly high volume of current measurements – with uncontrolled errors ("white noise"). Moreover, such statistical investigations would have been too costly from the standpoint of economy. Therefore, the reliability of such models of calculating contaminated areas of urban outside air and contaminants transfer in cities is so far questionable.

6. The Classic Apparatus of Differential Equations in Partial Derivatives and Mathematical Physics Apparatus

The choice of a classical apparatus of differential equations in partial derivatives and a powerful apparatus of mathematical physics – as means of investigating the problem of urban atmosphere contamination by vehicles, is connected with the following factors [4]:

- the apparatus of mathematical physics allows one to use fundamental laws of physics – such as the laws of turbulent molecular scattering, turbulent atmosphere dynamics, the law of transfer in heterogeneous mediums, the laws of hydro- and gas dynamics, – and for developing the non-standard 3D-mathematical model to determine the dynamics of exhaust emission level in urban outside air – provided the air flow rate is not unknown *apriori.* Since all the above-mentioned fundamental laws of physics are described by linear and non-linear equations in partial derivatives, - the developed mathematical model is obviously described in terms of differential equations;
- the rich apparatus of differential equations in partial derivatives allows one to do the following, putting aside the specific object domain: analyse obtained differential equations (non-linear ones in general), investigate their correctness, perform a qualitative analysis, develop solutions through numerical or analytical methods, investigate issues of unicity and solution stability with respect to small variations of input data.

A direct connection of differential equations theory with the nature and physics of the processes should be emphasized. Describing mathematics as a method of penetration into the secrets of nature, investigator, first of all, creates its mathematical idealization. In other words, investigator neglecting the minor characteristics of a phenomenon expresses the main laws governing the phenomenon, in calculus notation. Quite frequently, these laws can be expressed as differential equations. This applies to models of various phenomena of continuum mechanics, chemical reactions, etc.

7. Example of Application of the Second Approach

As an example, the model used by the author in the works [10, 11] is presented. In [10, 11], the desired concentration of each harmful substance at any point of a confined 3D-area, and at any point of time interval within which the process of the exhaust gases concentration dynamics is investigated. In the example, the received theoretical mathematical results are used with respect to a specific district of Riga, where the road traffic is one of the most intensive. The task of determining the concentration dynamics of each of the seven harmful substances – CO, CO_2, NO, NO_2 and some others at various altitudes from the ground surface, i.e. in layers parallel to the ground surface, is investigated. The boundaries of each layer have been determined empirically, while the upper boundary of the layer the most distant from the ground surface was taken as equal to 75 m. taking into account the specific character of buildings in the city of Riga: $75\,m = M_{floor} \times 3\,m$ where M_{floor} is the number of floors of highest building in Riga. Kr. Valdemara Street has been taken as an example.

With respect to this task, let $C^{\{n\}}\left(x_1, x_2, x_3, t\right)$ denote the concentrations of n-th substance at the point $\left(x_1, x_2, x_3\right) \in \left[0, l_1\right] \times \left[0, l_2\right] \times \left[0, l_3\right]$ at any moment of time $t \in \left[0, T\right]$, where $n = \overline{1, \tilde{N}}$, $l_i \in R_+^1$ $\left(i = \overline{1,3}\right)$, T – time during which the concentration changing process is investigated, while $\tilde{N}$ is the number of substances the concentration of which should be determined. For each fixed $n = \overline{1, \tilde{N}}$ in the closed region $\left[0, l_1\right] \times \left[0, l_2\right] \times \left[0, l_3\right] \times \left[0, T\right]$, the function $C^{\{n\}}\left(x_1, x_2, x_3, t\right)$, consistent with the equation

$$\begin{aligned} &\frac{\partial C^{\{n\}}\left(x,t\right)}{\partial t} = div\left(D^2\left(x\right) \cdot \overrightarrow{grad} C^{\{n\}}\left(x,t\right)\right) - \vec{\vartheta}\left(x,t\right) \cdot \overrightarrow{grad} C^{\{n\}}\left(x,t\right), \\ &x = \left(x_1, x_2, x_3\right):\ 0 < x_i < l_i,\ t > 0,\ n = \overline{1, \tilde{N}}, \end{aligned} \quad (5)$$

should be found;

where the eddy diffusion coefficient and the molecular diffusion coefficient $D^2\left(x\right)$ is the piecewise constant function of the number of stratified mediums parallel to the plane X_1OX_2 along the vertical axis OX_3, the initial condition $C^{\{n\}}\left(x,t\right)\Big|_{t=0} = C_0^{\{n\}}\left(x\right)$, $x = \left(x_1, x_2, x_3\right):\ 0 \le x_i \le l_i$, the boundary conditions at each fixed $j = \overline{0, M-1}$ [10,11].

It follows from the formula (5) that, basically, there is a possibility of finding the desired concentration of each harmful substance at each point of the confined space, at each moment of time. It should be noted that the solution according to the formula (5) is not trivial.

8. Conclusions

This work, by making specific references to investigation of ecological problems shows the legitimacy of two approaches: the apparatus of the theory of chance and mathematical statistics and the conceptually alternative approach connected with using the apparatus of the theory of differential equations in partial derivatives and equations of mathematical physics. The investigation comes to the conclusion that the second approach manages to penetrate deeper into the physical essence of the examined phenomena and yielding analytical results directly connected with the physical aspect of a particular process. Investigator faces the prospects of receiving precise or approximate results with respect to the process in its dynamic development; he also get the possibility of forecasting the course of a particular physical phenomenon without the necessity of collecting a huge volume of statistical data. The second approach is deeper and more comprehensive – for example, if problems of motor traffic ecology are to be solved. On the other hand, the expediency of using approaches of the theory of chance and mathematical statistics is not argued. The two approaches, not conflicting with each other, are useful and mutually complementary. The task of the author is to show the legitimacy and the advantages of using a powerful apparatus of mathematical physics in cases where only the apparatus of probabilistic approaches is currently used as a rule.

References

1. Marchuk, G.I. *Matematicheskoe modelirovanie v probleme okruzhajuschei sredi*. M.: Nauka, 1982. 319 p.
2. Marchuk, G.I., Kondratjev, K.J. *Prioriteti globalnoj ekologii*. M.: Nauka, 1992. 263 p.
3. Gringlaz, L.Ya., Kopytov, E.A. *Mathematical Statistics with Example of Task Solving on the Computer*. Riga: VShEK, 2002. 326 p.
4. Yatskiv, I.V. *Multidimensional Statistical Analysis: Classification and Decrease of Dimensionality*. Riga: TSI, 2003. 200 p.

5. Vorobejnik, E.L., Sadykov, O.F., Farafontov, M.G. *Jekologicheskoe normirovanie tehnogennyh zagrjaznenij nazemnyh ekosistem*. Ekaterinburg: Nauka, 1994.
6. Penenko, V.V. Aloyan, A.E. *Models and Methods of Solving Environment Protection Problems.* M.: Nauka, 1985. 256 p.
7. Marchuk, G.I., Zilitinkevich, S.S., Chalikov, D.V. Opredelenie universal'nyh profilej skorosti vetra i temperatury v prizemnom sloe atmosfery, *Fizika atmosfery i okeana*, Vol. 4, No 3, 1968, pp.294-302.
8. Zilitinkevich, S., Esau, I., Baklanov, A. Atmospheric boundary layers in storms: advanced theory and modelling applications, *Journal of Advances in Geosciences*, Vol. 2, 2005, pp. 47-49.
9. Penenko, V.V., Alojan, A.E. *Modeli i metody dlja zadach ohrany okruzhajuwej sredy*. M.: Nauka, 1985. 256 p.
10. Grishin, S., Rimshans, J.S., Kopytov, E.A., Guseynov, Sh.E., Schiptsov, O.V. Time-dependent problem for determination of exhaust concentration under known air flow velocity. In: *Proceedings of the International Conference on Modelling of Business, Industrial and Transport Systems (MBIT), May 07-10, 2008, Riga, Latvia.* Riga, 2008, pp. 177-184.
11. Guseynov, Sh.E., Kopytov, E.A., Grishin, S., Schiptsov, O.V., Rimshans, J.S. Mathematical model for determination of exhaust concentration dynamics in urban atmosphere under unknown turbulent airflow velocity. In: *Extended Abstracts of the International Conference "RELIABILITY and STATISTICS in TRANSPORTATION and COMMUNICATION (RelStat`08)", October 15-18, 2008, Riga, Latvia.* Riga: TTI, 2008. 5 p.

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

Authors' index

CUMULATIVE INDEX

TRANSPORT and TELECOMMUNICATION, Volume 10, No 1, 2009
(Abstracts)

López-Neri, E. Hiearachical Agent-Based Modelling: A Guadalajara City Case Study on Urban Traffic Simulation. *Transport and Telecommunication*, Vol. 10, No 1, 2009, pp. 4–13.

In this paper a microscopic discrete event urban traffic model validation using simulation is presented. In a previous study a hierarchical microscopic urban traffic system (UTS) model was developed [1]. That model integrates the event oriented and agent-based approach. The UTS is described using the multi-level Petri net based formalism, named n-LNS. The first level describes the traffic network; the second level models the behaviour of diverse road network users considered as agents, and the third level specifies detailed procedures performed by the agents, namely travel plans, tasks, etc.. Usually simulators are designed using time step approach and are validated using real data and is verified that the flow/density relationship (fundamental diagram) are conserved and then state the simulator generates a valid behaviour. However, the model used in this paper uses the event oriented approach, doing more complex the process to obtain these validation graphs and their corresponding analysis. In order to validate it, was developed a library known as *CiudadelaSim* [1].

Keywords: discrete event, traffic simulation, microscopic validation, n-LNS, Petri nets

Gromov, G. A Statistical Sample Analysis of Latvian Logistics Services. *Transport and Telecommunication*, Vol. 10, No 1, 2009, pp. 14–19.

In the analysis are represented collected data, poll opinions and their interpretation of Latvian logistics service. The focus was made for three groups of companies: manufacturing/construction companies, trading companies, logistics service providers. In research mainly analyzed micro, small and medium size enterprises. The important Latvian logistics costs (transportation, warehousing, administration) and their trends are compared with similar US logistics characteristics. The results are used in LogOn Baltic project

Keywords: Logistics, costs, indicators

Chernodarov, A. Bench Development of Navigation Algorithms by Application of Object-Oriented Technologies. *Transport and Telecommunication*, Vol. 10, No 1, 2009, pp. 20–29.

Special features of implementing an object-oriented technology for the integration of navigation sensors in strapdown inertial satellite systems (SISNS) are considered. A block diagram of the object-oriented hardware support and object-oriented mathematical-software support for the SINS-1000 system built around fiber-optic gyros is given. The results of testbed experiments of the SINS-1000 system are presented, which corroborate the fact that it is possible and expedient to apply the proposed technology to the creation of different-purpose SISNSs, which can be made to order.

Keywords: navigation systems, fiber-optic gyros, object-oriented technology, half-scale modeling

Kapskij, D. Development of the System of Road Traffic Safety Improvement in Accident Seats of Urban Areas**.** *Transport and Telecommunication*, Vol. 10, No 1, 2009, pp. 30–37.

The analysis of the developed system of increase of road traffic safety in the city centres of road accidents is resulted. The block diagram of the given system has been received; lacks of the existing position are reflected. The description of necessary actions for creation of methodological base of increase of road safety of traffic in the city centres of road accidents in Byelorussia is performed.

In the article substantive provisions on the road traffic organisation in the city centres the road accidents, which are based on the account of all kinds of losses in road traffic and an estimation of quality of accepted decisions are resulted. Practical, scientific and scientifically-methodical problems on creation the system of safety increase of road traffic are defined.

Keywords: losses in road traffic, methodology of accident forecasting, accident losses, forecasting methods

Grishin, S. Problem of Mathematical Instrument Selection for the Purpose of Investigation of Exhaust Gases Dynamics in Urban Air. *Transport and Telecommunication*, Vol. 10, No 1, 2009, pp. 38–47.

This work, by making specific references to investigation of ecological problems shows the legitimacy of two approaches: the apparatus of the theory of chance and mathematical statistics and the conceptually alternative approach connected with using the apparatus of the theory of differential equations in partial derivatives and equations of mathematical physics. The investigation comes to the conclusion that the second approach manages to penetrate deeper into the physical essence of the examined phenomena and yielding analytical results directly connected with the physical aspect of a particular process. Investigators face the prospects of receiving precise or approximate results with respect to the process in its dynamic development; they also get the possibility of forecasting the course of a particular physical phenomenon without the necessity of collecting a huge volume of statistical data. The second approach is deeper and more comprehensive – for example, if problems of motor traffic ecology are to be solved. On the other hand, the expediency of using approaches of the theory of chance and mathematical statistics is not argued. The two approaches, not conflicting with each other, are useful and mutually complementary. The task of the author was to show the legitimacy and the advantages of using a powerful apparatus of mathematical physics in cases where only the apparatus of probabilistic approaches is currently used as a rule.

Keywords: anthropogenic pollutions, exhaust gases, mathematical statistics, dynamics, partial differential equations, mathematical physics equations

TRANSPORT and TELECOMMUNICATION, 10.sējums, Nr.1, 2009 (Anotācijas)

Lopezs-Neri, E. Hierarhiska uz aģentu bāzēta modelēšana: satiksmes simulācijas izpēte Guadalajara pilsētā. *TRANSPORT and TELECOMMUNICATION,* 10.sēj., Nr.1, 2009, 4.–13. lpp.

Autors savā rakstā parāda detalizēta diskrēta notikuma pilsētas satiksmes modeļa vērtēšanu, lietojot simulāciju. Iepriekšējā pētījumā tika izveidots hierarhisks detalizēts pilsētas satiksmes sistēmas (*UTS – urban traffic system*) modelis [1]. Šis modelis integrē uz notikumu orientētu un uz aģentu bāzētu pieeju. *UTS* ir aprakstīta kā multi-līmeņa uz Petri tīklu bāzēts formālisms, saukts par *n-LNS*. Pirmais līmenis apraksta satiksmes tīklu; otrais līmenis modelē satiksmes ceļu tīkla lietotāju uzvedību, kas tiek uzskatīti par aģentiem, bet trešais līmenis precizē detalizētas procedūras, ko veic aģenti, precīzāk, ceļojuma plāni, uzdevumi, etc.

Lai gan modelis, kas tiek aprakstīts šajā rakstā, pielieto pieeju orientētu uz notikumu, veicot vēl sarežģītāku procesu, lai iegūtu vērtējuma diagrammu un atbilstošu tam analīzi. Lai to novērtētu, ir radīta bibliotēka, kas zināma kā *CiudadelaSim* [1].

Atslēgvārdi: diskrēts notikums, satiksmes simulācija, detalizēts vērtējums, *n-LNS*, Petri tīkls

Gromovs, G. Latvijas loģistikas pakalpojumu statistiskā piemēra analīze. *TRANSPORT and TELECOMMUNICATION,* 10.sēj., Nr.1, 2009, 14.–19. lpp.

Dotajā analīzē tiek parādīti savāktie dati un to interpretācija Latvijas loģistikas pakalpojumos. Akcents tika likts uz trīs grupu kompānijām: ražošanas/būvniecības kompānijām, tirdzniecības kompānijām un loģistikas pakalpojumu sniedzējiem. Pētījumā galvenokārt tika analizēti sīkie, mazie un vidējie uzņēmumi. Svarīgās Latvijas loģistikas izmaksas (transportēšana, uzglabāšana, administrēšana) un to virzieni ir salīdzinātas ar līdzīgiem ASV loģistikas raksturojumiem. Rezultāti tika pielietoti LogOn Baltijas projektā.

Atslēgvārdi: loģistika, izmaksas rādītāji

Černodarovs, A. Navigācijas algoritmu praktiskā izstrāde, pielietojot objektu orientētas tehnoloģijas. *TRANSPORT and TELECOMMUNICATION,* 10.sēj., Nr.1, 2009, 20.–29. lpp.

Tiek izskatītas objektu orientētas tehnoloģijas realizācijas īpatnības strapdown inerciāla satelītu sistēmas (*strapdown inertial satellite systems – SISNS*) integrācijai. Tiek izskatīta objektu orientētas skaitļošanas aparatūras nodrošinājuma blokshēma un objektu orientētas matemātiskās programmatūras nodrošinājums SINS-1000 sistēmai, uzbūvētai ap šķiedru optikas žiroskopiem. Tiek parādīti eksperimentu rezultāti, kuri apstiprinās ar faktu, ka tas ir iespējams, un ir lietderīgi pielietot piedāvāto tehnoloģiju, lai radītu dažādiem nolūkiem paredzēto satelītu navigācijas sistēmu – *SISNS*, kura var tikt izveidota pēc pasūtījuma.

Atslēgvārdi: navigācijas sistēmas, šķiedru optikas žiroskopi, uz objektu orientēta tehnoloģija, pusmēroga modelēšana

Kapskijs, D. Ceļu satiksmes drošības sistēmas attīstība sadursmju vietu uzlabošana pilsētā. *TRANSPORT and TELECOMMUNICATION,* 10.sēj., Nr.1, 2009, 30.–37. lpp.

Rakstā ir veikta ceļu satiksmes drošības sistēmas uzlabošanas analīze pilsētas centrā sadursmju vietās. Dotās sistēmas diagrammu daudzums ir iegūts pētījuma rezultātā; tiek parādīti esošās sistēmas trūkumi. Autors dod arī nepieciešamo darbību aprakstu, lai radītu satiksmes drošības sistēmas uzlabošanas metodoloģisko pamatu ceļu satiksmes negadījumiem Baltkrievijas pilsētu centros.

Praktiskās, zinātniskās un zinātniski metodiskās problēmas tiek noteiktas, lai radītu sistēmu ceļu satiksmes drošības uzlabošanai.

Atslēgvārdi: zaudējumi ceļu satiksmē, metodoloģija ceļu satiksmes negadījumu paredzēšanā, prognožu metodes

Grišins, S. Matemātiskā instrumenta izvēles problēma izplūdes gāzu dinamikas izpētei pilsētas gaisā. *TRANSPORT and TELECOMMUNICATION,* 10.sēj., Nr.1, 2009, 38.–47. lpp.

Autors savā rakstā parāda, veicot īpašu ekoloģiskas problēmas izpēti, divu pieeju likumību: varbūtību teorijas un matemātiskās statistikas aparātu un konceptuāli atšķirīgu pieeju saistītu ar diferenciālvienādojumu teoriju daļējos atvasinājumos un matemātiskās fizikas vienādojumu aparātu. Pētījumā var izdarīt secinājumu, ka otrā pieeja iespēj iespiesties dziļāk izpētītā fenomena fizikālajā būtībā, un, iegūstot analītiskus rezultātus, tieši saistīta ar konkrētā procesa fizikālo aspektu. Otrā pieeja ir dziļāka un labāk saprotama. Šīs divas pieejas, nekonfliktējot viena ar otru, ir lietderīgas un savstarpēji papildinošas. Autora nodoms bija parādīt likumību un priekšrocības, lietojot spēcīgu matemātiskās fizikas aparātu tajos gadījumos, kur tikai varbūtību pieeju aparāts var tikt, kā likums, pielietots.

Atslēgvārdi: antropogēni piesārņojumi, izplūdes gāzes, matemātiskā statistika, dinamika, daļējie diferenciālvienādojumi, matemātiskās fizikas vienādojumi

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.

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 1
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

PREPARATION OF CAMERA-READY TYPESCRIPT: COMPUTER MODELLING AND NEW TECHNOLOGIES

1. In order to format your manuscript correctly, see the Page Layout Guideline for A4 (21 cm x 29,7 cm) paper size. Page Layout should be as follows: Top – 3 cm, Bottom – 3 cm, Left – 3 cm, Right – 3 cm.
2. Maximum length for the article is **10 pages**.
3. **Using of other Styles with the exception of Normal is not to be allowed!**
4. ***Articles*** should be Times New Roman typeface, single-spaced.
5. The article should include:
   - title;
   - author's name(s) and information (institution, city, country, the present address, phones, and e-mail addresses);
   - abstract (100-150 words);
   - keywords (max. 6);
   - introduction – clear explanation of the essence of the problem, previous work, purpose of the research and contribution;
   - description of the research;
   - conclusion section (this is mandatory) – should clearly indicate on the advantages, limitations and possible applications;
   - references.

   Attention! First name, last name, the title of the article, abstract and keywords must be submitted in the English and Latvian languages (in Latvian it is only for Latvian authors) as well as in the language of the original (when an article is written in different language).
6. The text should be in clear, concise English (or other declared language). Please be consistent in punctuation, abbreviations, spelling (***British English***), headings and the style of referencing.
7. ***The title of the article*** – 14 point, UPPERCASE, style Bold and centred.
8. ***Author's names*** – centred, type size 12 point, Upper and lower case, style Bold Italic.
9. ***Author's information*** – 10 point, Upper and lower case, style Italic, centred.
10. ***Abstract and keywords*** – 8 point size, style Normal, alignment Justify.
11. ***The first level Headings*** – 11 point, Upper and lower case, style Bold, alignment Left. Use one line space before the first level Heading and one line space after the first level Heading.
12. ***The second level Headings*** – 10 point, Upper and lower case, style Bold, alignment Left. One line space should be used before the second level Heading and 1/2 line space after the second level Heading.
13. ***The third level Headings*** – 10 point, Upper and lower case, style Italic, alignment Left. One line space should be used before the second level Heading and 1/2 line space after the third level Heading.
14. ***Text*** of the article – 10 point, single-spaced, alignment Justify.
15. The set of ***formulas*** on application of fonts, signs and a way of design should be uniform throughout the text. The set of formulas is carried out with use of editors of formulas MS Equation 3.0 or MathType. The formula with a number – the formula itself should be located on the left edge of the text, but a number – on the right one. Font sizes for equations are the following: 11pt – full, 7pt – subscripts/superscripts, 5pt – sub- subscripts/superscripts, 16pt – symbols, 11pt – subsymbols.
16. All ***Figures*** – must be centred. Figure number and caption always appear below the Figure, type size 8 point.

Figure 1. This is figure caption

Diagrams, Figures and Photographs – must be of high quality, in format *.TIFF, *.JPG, *.BMP with resolution not less than 300 dpi. Also formats *.CDR, *.PSD are possible. Combination of Figures in format, for instance, *.TIFF with elements of the in-built Figure Editor in MS Word is prohibited.

17. ***Table Number and Title*** – always appear above the Table. Alignment Left. Type size 8 point. Use one line space before the Table Title, one line space after the Table Title and 1/2 line space after the Table.

Table 1. This is an example of a Table

Heading	**Heading**	**Heading**
Text	Text	Text
Text	Text	Text

18. ***References*** in the text should be indicated by a number in square brackets, e.g. [1].
References should be numbered in the order cited in the manuscript. The correct format for references is the following:

Article: author, title, journal (in italics), volume and issue number, year, inclusive pages

Example: 1. Amrahamsson M., Wandel S. A Model of Tearing in Third – Party Logistics with a Service Parts Distribution Case Study, *Transport Logistics*, Vol. 1, No 3, 1998, pp. 181-194.

Book: author, title (in Italics), location of publishers, publishers, year, whole pages

Example: 2. Kayston M. and Fried W. R. *Avionic Navigation Systems.* New York: John Wiley and Sons Inc, 1969. 356 p.

Conference Proceedings: author; title of an article; proceedings (in italics); title of a conference, date and place of a conference; publishing house, year, concrete pages

Example: 3. Canales Romero J. A First Step to Consolidate the European Association of Aerospace Students in Latvia (Presented by the Munich Local Group). In: *Research and Technology – Step into the Future: Programme and Abstracts. Research and Academic Conference, Riga, Latvia, April 7–11, 2003, Transport and Telecommunication Institute.* Riga: TTI, 2003, p. 20.

19. ***Authors Index***
Editors form the author's index of a whole Volume. Thus, all contributors are expected to present personal colour photos with the short information on the education, scientific titles and activities.

20. ***Acknowledgements***
Acknowledgements (if present) mention some specialists, grants and foundations connected with the presented paper. The first page of the contribution should start on page 1 (right-hand, upper, without computer page numbering). Please paginate the contributions, in the order they are to be published. Use simple pencil only.

21. **Articles poorly produced or incorrectly formatted may not be included in the proceedings**.