THE 14TH INTERNATIONAL CONFERENCE ON HARBOR, MARITIME & MULTIMODAL LOGISTICS MODELLING AND SIMULATION

SEPTEMBER 19-21 2012

VIENNA, AUSTRIA

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Welcome To HMS 2012!

Welcome to the 14th International Conference on Harbor, Maritime & Multimodal Logistics Modelling and Simulation, that is a great opportunity for worldwide scientists and experts to share experiences, researches, studies and applications related to maritime environment, logistics and supply chain management issues.

HMS is a traditional event and it has been held successfully worldwide, usually in the surroundings of major international ports such as Genoa (1999) or Marseille (2001), Gioia Tauro (2008), etc.

The tracks, special sessions and workshops, which are part of HMS, provide a great overview of the recent activities in this field, which is increasingly important for the whole society above considering the recent financial crisis (still on going in many countries); in fact in each country Logistics and Supply Chains operations may positively or negatively affect the richness of the country and therefore its economy.

Within this framework, simulation has proved to be very effective to support decision making and training. The HMS 2012 conference is an ideal framework for authors that present innovative technologies and advanced solutions based on Modeling and Simulation that could represent a valid support for experts, authorities and operators in maritime sector to plan effective actions, to optimize supply chain, to improve transportation systems and services or simply to train people.

The success of HMS 2012 is related to the strong efforts of the international Program Committee that, also this year, has worked hardly to review and select high quality papers and scientific works. Therefore we appreciate reviewers' work and thank them for their useful cooperation. Last but not least, a special thank goes to the authors that are the main contributors of HMS success.

Lastly, we would like to wish all the conference attendees to enjoy Vienna, the "city of music", and to have a fruitful and memorable time during the HMS 2012 Conference

Agostino Bruzzone,
MITIM-DIME, University Of Genoa, Italy

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The HMS 2012 International Program Committee (IPC) has selected the papers for the Conference among many submissions; therefore, based on this effort, a very successful event is expected. The HMS 2012 IPC would like to thank all the authors as well as the reviewers for their invaluable work.
A special thank goes to all the organizations, institutions and societies that have supported and technically sponsored the event.

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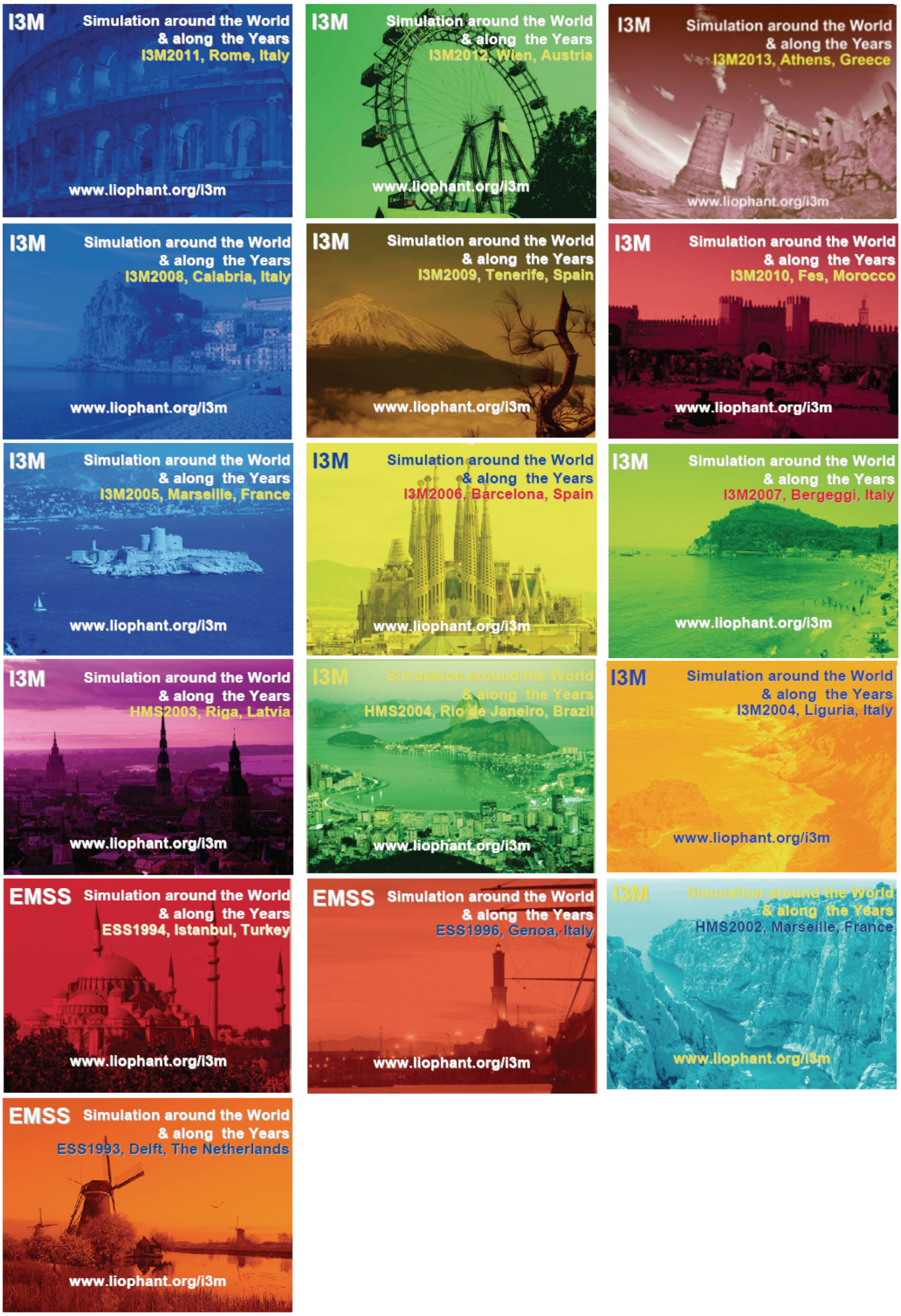

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SAFETY CONTROL OF LATVIAN STATE ROAD NETWORK USING STATISTICAL MODELLING METHODS

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ABSTRACT

Latvia has recently seen an increase in volumes of exports and imports of goods, and volumes of cargo transit through the territory of Latvia have also increased. The results of the study of the Latvian Road Carrier Association show that, in 2011, the Latvian trucking companies' freight turnover increased by 20%. At the same time, the number of cars and trucks registered in Latvia is also increasing. The intensity of vehicular traffic on roads of Latvia increases too, especially, the transit traffic on the main roads of Latvia. The aim of this research is to model the incidence of road traffic accidents and populated areas (towns) that occur on the main (national) highways of Latvia and estimate the expected interval of variations in the real damage incurred by the state.

The research envisages the creation of the following models:

1. to determine the possible number of road traffic accidents on the main (public) roads;
2. to calculate the damage (general economic losses $\mathbf{C_{Total}}$) caused for the national economy of Latvia due to road traffic accidents.

The authors believe that the effectiveness of the logistics process should be evaluated not only taking into consideration the volume of goods transported, and the profit derived from it, but should also assess the losses incurred by the state due to increased road traffic accidents and fatalities, destruction of vehicles and road surfaces, and so on. In this research, using statistical modelling, we determine the relationship between parameters describing the state of road infrastructure in Latvia, and intensity on the roads of Latvia, as well as economic losses due to increased intensity of the logistics process and increased numbers of road traffic accidents (resulting value).

Keywords: road accidents, statistical modelling, Monte-Carlo method, management, effectiveness

1. INTRODUCTION

The geographical location of Latvia is extremely favourable for the development of the transport business, since Latvia has ports capable of receiving and serving all classes of ships, as well as an extensive transportation network of railways and highways connecting the ports of Latvia with the CIS countries and the EU (see Figure 1). Roads are an important component of Latvian transport system with the total length of 20,309 km.

Figure 1: The Basic Directions of Road Traffic on Territory of Latvia

Losses on roads have big social and economic value for each country. The information about World road traffic accidents (number of injured and killed in road accidents) is shown in Figures 2 and 3.

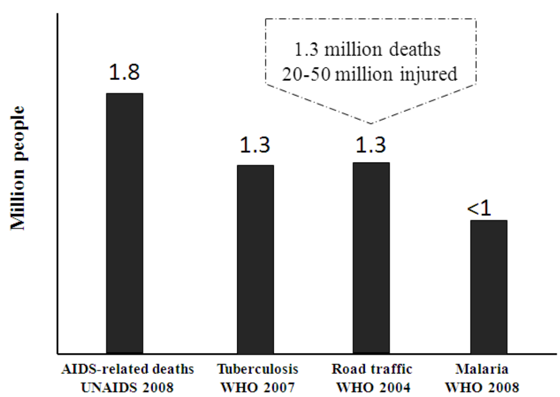

Figure 2: Road Traffic Deaths: the Facts (One-year progress update: Decade of Action for Road Safety 2011-2020)

Proceedings of the International Conference on Harbor Maritime and Multimodal Logistics M&S, 2012
ISBN 978-88-97999-11-9; Bruzzone, Gronalt, Merkuryev, Piera, Talley Eds.

2004: the Facts		
Rank	**Disease or Injury**	**%**
1	Ischaemic heart disease	12.2
2	Cerebrovascular disease	9.7
3	Lower respiratory infections	7.0
4	Chronic Obstructive Pulmonary Disease	5.1
5	Diarrhoeal diseases	3.6
6	HIV/AIDS	3.5
7	Tuberculosis	2.5
8	Trachea, bronchus, lung cancer	2.3
9	**Road traffic injuries**	**2.2**
10	Prematurity and low-birth weight	2.0

2030: the Prediction		
Rank	**Disease or Injury**	**%**
1	Ischaemic heart disease	14.2
2	Cerebrovascular disease	12.1
3	Lower respiratory infections	8.6
4	Prematurity & low-birth weight	3.8
5	**Road traffic injuries**	**3.6**
6	Trachea, bronchus, lung cancer	3.4
7	Diabetes mellitus	3.3
8	Hypertensive heart disease	2.1
9	Stomach cancer	1.9
10	HIV/AIDS	1.8

Figure 3: Leading causes of death, 2004 and 2030 compared (Global status report on road safety 2009)

The forecast (see Figure 3) for high-income countries, current and projected trends in low-income and middle-income countries foreshadow a big escalation in global road crash mortality between 2000 and 2020. Furthermore, on current trends, by 2020, road crash injury is likely to be the third leading cause of disability-adjusted life years lost. In economic terms, the cost of road crash injuries is estimated at roughly 1% of gross national product (GNP) in low-income countries, 1.5% in middle-income countries and 2%-3% in high-income countries (Global status report on road safety 2009).

The annual material damage due to road traffic accidents on roads, in Latvia, is presented in Table 1.

Table 1: Annual Damage Incurred to Road Traffic Accidents on the main roads in Latvia

Year	Annual Damage, mln. LVL, **C_fact**	Road transport - accidents (road_ac), x_1	People killed in road accidents (road_ac_death), x_2	Number of injured victims, x_3	Model of annual damage, mln. LVL, **C_mod**
1996	79,8	13656	550	4324	86,43
1997	94,4	17328	525	4674	105,19
1998	136,7	25655	627	5414	145,28
1999	152,4	30614	604	5244	151,01
2000	157,9	20454	588	5449	135,23
2001	190,6	36468	517	5852	182,67
2002	207,0	39593	518	6300	203,08
2003	211,3	45555	493	6639	226,48
2004	220,8	48912	516	6416	226,89
2005	210,4	47353	442	5600	199,07
2006	203,7	52102	407	5404	203,62
2007	244,5	61383	419	6088	244,54
2008	208,9	54323	316	5408	209,03
2009	122,6	35058	254	3930	122,51
2010	132,7	38343	218	4023	132,67

2. PROBLEM DESCRIPTION

To build a statistical model it is necessary to investigate:

- traffic intensity on each of the sections of road transport route;
- number of intersections with the other highways;
- number of populated areas, through the territory of which, highways run (the existing empirical data show that biggest concentration of the black spots is evidenced in the populated areas. Moreover, the bigger the populated area, the greater the number of road traffic accidents, i.e., black spots;
- statistics of road traffic accidents on the section of the route of traffic.

The scheme of the i^{th} route of traffic with the relevant road traffic parameters of every section of the route from point A to point B is presented in Figure 4.

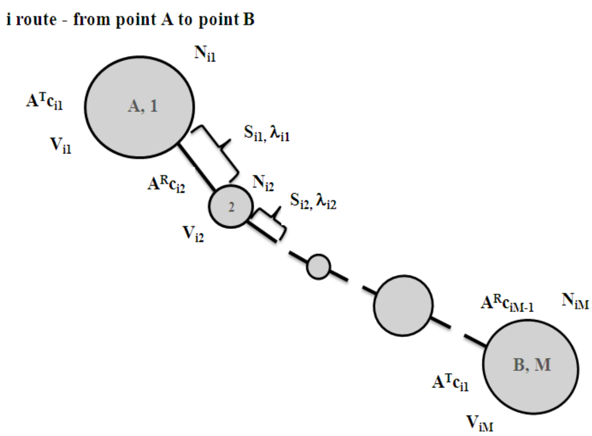

Figure 4: Scheme of the i^{th} Route of Road Traffic between Points of Populated Areas A and B

Parameters of the route scheme (Figure 4):

A^Tc_{ij} – incidence of road traffic accidents occurring in the j^{th} populated area (town) i=1,2,…,R; j=1,2,…,M;

N_{ij} – number of population in the j^{th} populated area (town) of the of i^{th} route of traffic i=1,2,…,R; j=1,2,…,M;
V_{ij} – number of transport vehicles in the j^{th} populated area (town), i=1,2,…,R; j=1,2,…,M;
λ_{ij} – intensity of road transport vehicle movement in the j^{th} section of the i^{th} route of traffic, i=1,2,…,R; j=1,2,…,M-1;
$A^{R}c_{ij}$ – incidence of road traffic accidents occurring in the j^{th} sector of the of i^{th} route of traffic, i=1,2,…,R; j=1,2,…,M-1;
S_{ij} – length of the j^{th} sector of the of i^{th} route of traffic, i=1,2,…,R; j=1,2,…,M-1.
R – number of main state routes, R=I, II, …,X.

For statistical modeling of number of accidents as a result of the auto failures occurring in cities, the scheme is used (see Figure 5).

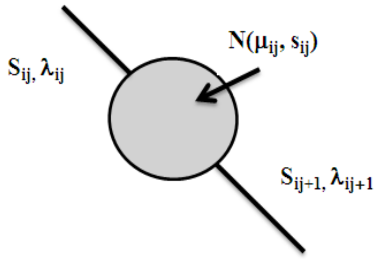

Figure 5: Intensity of Road Traffic Accidents Occurring in Crossed City in the i^{th} Route of Traffic

In Figure 5, $N(\mu_{ij}, \sigma_{ij})$ denotes the normal distribution of the number of road traffic accidents per unit of time (the normal distribution quite well describes the distribution of the number of road traffic accidents, occurring in the populated areas). At sections of roads located outside the populated areas, the number of road traffic accidents occurring per unit of time is described by Poisson distribution with the parameter λ_{ij}, i=1,2,…,R; j=1,2,…,M-1.

The modelling of annual material damage due to road traffic has been performed using the simplified structure of main roads of Latvia (see Figure 6).

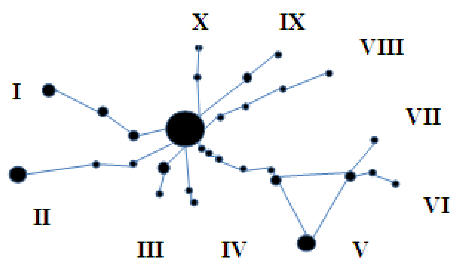

Figure 6: Scheme of Main Road Traffic Routes and Crossed Cities

Using the parameters mentioned above, the total number of road traffic accidents, occurring on the i^{th} route of traffic, can be determined using statistical modelling methods. Thus, it becomes possible to calculate the total expected incidence rate of road traffic accidents on major highways in Latvia.

Having at our disposal the statistical information about material damage, incurred by state, by each type of road traffic accidents occurring on roads, as well as having modelled the incidence rate of road traffic accidents, we may calculate the possible range of variations in the total damage due to road traffic accidents on main roads in Latvia.

In accordance with the evaluation of experts of the Ministry of Economics, the GDP growth could reach 5.5% in 2011 (see Table 2). The more rapid development scenario foresees that growth rates of manufacturing (and respectively also exports) will remain comparatively fast also after 2012, based mainly on both the increased competitiveness of Latvian producers and on the growth of external demand. The slower development scenario assumes that the growth in Europe will be weak and competitiveness in tradable sectors will not improve in the medium-term (see Figure 7).

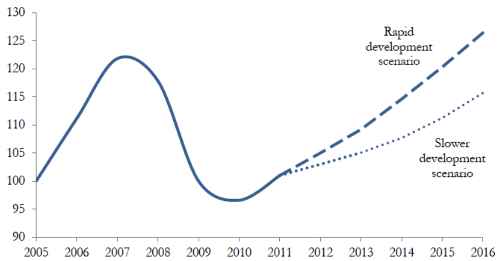

Figure 7: Forecasts of Latvian GDP (Report on the Economic Development of Latvia, December 2011, (Report of Economic Development of Latvia December 2011)

The growth of the economy of Latvia will not exceed 3% in 2012. Yet, considering many uncertainties about possibilities of solving several big debt problems in the euro zone and their potential impact on the real sector of these countries, the Ministry of Economics has prepared also the more pessimistic forecast of 1.5% growth of GDP in 2012 (Economic Development of Latvia, Report 2011).

Table 2: Forecast of Latvian GDP

Forecast of Latvian GDP by Expenditure Items in % over the previous year			
Years	2011	2012	average annually 2013-2016
%	5.5	1.5..3.0	3.0..4.7

Road accidents cost up to 5 % of the gross domestic product – in many countries costs are around 1-3% of GDP. The amounts invested in road safety are likely to be smaller than the costs of accidents, although very few estimates of this are available.

Two scenario are investigated in the paper (Table 3).

Table 3: Two Scenarios Forecast of Latvian GDP Growth and Road Transport Accidents Annual Damage

Year	GDP prediction, thousands LVL		Annual Damage prediction, thousands LVL	
	Slow growth scenario	Rapid growth scenario	Slow growth scenario	Rapid growth scenario
2011	14161028 thousands LVL GDP fact 2011			
2012	14373443,4	14585858,8	215601,7	218787,9
2013	14804646,7	15271394,2	222069,7	229070,9
2014	15248786,1	15989149,7	228731,8	239837,2
2015	15706249,7	16740639,8	235593,7	251109,6
2016	16177437,2	17527449,8	242661,6	262911,7
2017	16662760,3	18351240,0	249941,4	275268,6
2018	17162643,1	19213748,3	257439,6	288206,2
2019	17677522,4	20116794,4	265162,8	301751,9
2020	18207848,1	21062283,8	273117,7	315934,3
2021	18754083,5	22052211,1	281311,3	330783,2
2022	19316706,0	23088665,0	289750,6	346330,0
2023	19896207,2	24173832,3	298443,1	362607,5
2024	20493093,4	25310002,4	307396,4	379650,0
2025	21107886,2	26499572,5	316618,3	397493,6

3. STATISTICAL MODEL

For statistical modelling of annual road transport accidents (road_ac), authors used mathematical model:

$$\sum_{i=1}^{R}\left[\sum_{j=1}^{M}\alpha\left(V_{ij}\right)^{\beta_1}\left(N_{ij}\right)^{\beta_2}+\sum_{j=1}^{M-1}\gamma_{ij}A_{c_{ij}}^{R}S_{ij}\right], \qquad (1)$$

where α, β_1, β_2 – coefficients for model of road accidents in Latvian cities (towns). γ_{ij} – coefficient describing factor risk for the the j^{th} section of the i^{th} route of traffic, i=1,2,…,R; j=1,2,…,M-1;

Using regression tool the model of evaluation of annual damage can be expressed as:

$$C_{\text{mod}}(x_1,x_2,x_3)=-71.9+0{,}002\cdot x_1-0{,}01\cdot x_2+ +0{,}03\cdot x_3\,, \qquad (2)$$

where x_1 – number of road transport accidents;
x_2 – number of people killed in road traffic accidents;
x_3 - number of injured victims.

Regression model (2) has a good approximation of real annual losses of economy (annual damage) of Latvia (see Figure 8).

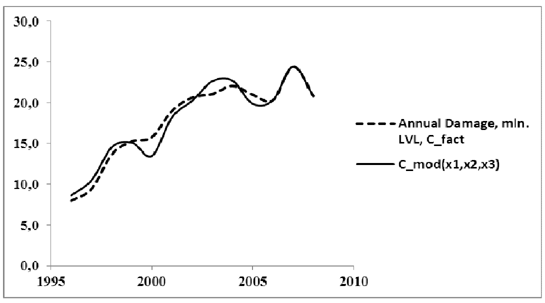

Figure 8: Graphical Illustration of Regression Model of Annual Damage and Real Road Traffic Accidents

The information presented in Figure 8 characterizes intensity of streams of movement of motor transport on modelled sites III, IV main roads A5, A7 and A8. Intensity of movement is shown by numbers, in the form of fraction, for example $\frac{3951}{1976}$. The top number means the general intensity of movement of motor transport on a site of the main road in unit of time (days). The bottom number characterizes intensity of movement of cargo motor transport on the given site of the main road in unit of time (days). Arrows in drawing designate places (black points) with the greatest frequency of occurrence of road accidents (autofailures). Numbers n1/n2/n3 characterizes quantity of road traffic accidents accordingly in 2007/2008/2009 years (see Figure 9).

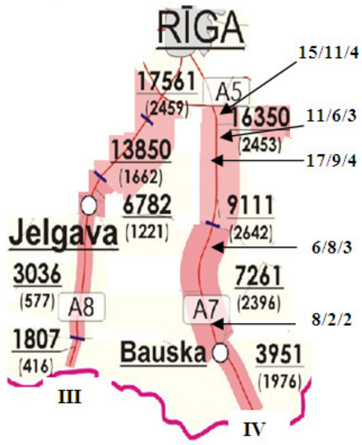

Figure 9: Traffic Intensity on Latvian Roads A5, A7, A8

Authors, using statistical modeling, have estimated the level of annual losses in economy of Latvia in connection with happened road traffic accidents, taking into account the factors influencing an infrastructure of the road system of the country. Using the statistical information characterizing the number of occurring accidents on main roads of Latvia for parameters x_1, x_2, x_3, authors define laws of statistical distribution for parameters x_1, x_2, x_3 and evaluate the confidential intervals for these parameters.

For evaluation of losses of Latvian economy from transport accidents on main Latvian roads such economic parameters are used:

y_1 - an average value of economic losses caused by one traffic road accident LVL.

y_2 - an average value of economic losses caused by one killed in traffic road accident, LVL.

y_3 - an average value of economic losses caused by one injured victims in traffic road accident, LVL.

For modeling the general economic losses of economy of Latvia as a result of transport accidents on the main roads of Latvia $\mathbf{C_{Total}}$, the formula is used:

$$C_{Total}=\sum_{i=1}^{3}x_i y_i\,, \qquad (3)$$

The number of failures on roads depends on two groups of factors – A - the factors raising number of failures on roads and B – the factors reducing number of failures on roads.

Factors belonging to group A:
- the number of the registered vehicles;
- the technical conditions of vehicles;
- the quality of roads and their infrastructure;
- the intensity of movement of transport streams;
- other factors.

Factors belonging to group B:
- the actions directed on improvement of quality of roads and related infrastructure;
- the investments for the realization of these actions ;
- other factors. In general, overall road safety budgets are allocated in relation to the national annual budget, GDP.

Using the statistical information (see Table 3, Figure 8, 9) and statistical modeling according to formulas (1, 2, 3) paper authors have received statistical distribution of general economic losses of Latvia $\mathbf{C_{Total}}$ for two scenarios – rapid and slow development of Latvian GDP (see Figure 7). The predicted values of each of parameters x_1, x_2, x_3, y_1, y_2, y_3 are presented in Figure 10, 11.

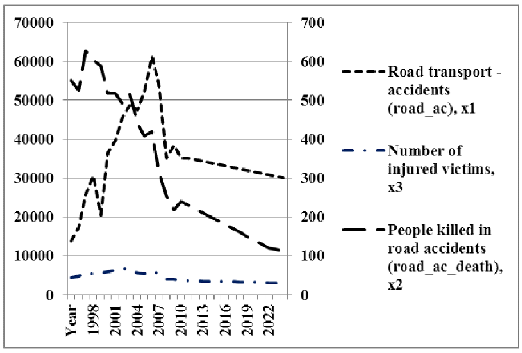

Figure 10: Road Transport Accidents x_1, x_2, x_3 Forecast

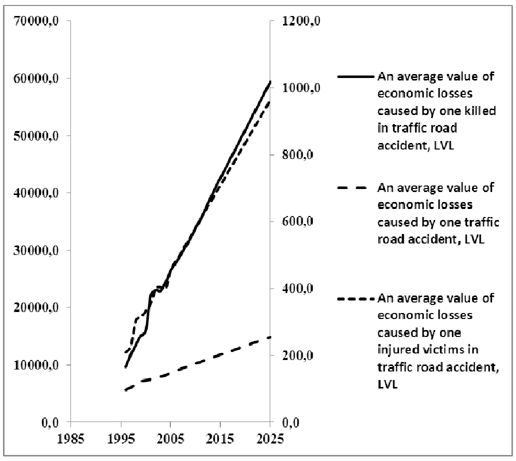

Figure 11: Parameters y_1, y_2, y_3 Forecast

The results of one realization of Monte-Carlo modeling method for parameters x_1, x_2, x_3 are shown in Table 4.

Table 4: The results of modeling for parameters x_1, x_2, x_3

Total, 2025 year		
N_CSNg =	**30623**	$\mathbf{x_1}$
N_bg =	**108**	$\mathbf{x_2}$
N_iev =	**3082**	$\mathbf{x_3}$

Forecast for parameters y_1, y_2, y_3 is shown in Table 5.

Table 5: Forecast for parameters y_1, y_2, y_3

Year	y_1, LVL	y_2, LVL	y_3, LVL
2025	**2555**	**593902**	**9633**

The fragment of modeling of $\mathbf{C_{Total}}$ (number of samples 5000) is shown in Table 6.

Table 6: The table of distribution for $\mathbf{C_{Total}}$

NN	Bin	Frequency	Rel Frequency	Cum Frequency
1	163635638,2	8	0,00160	0,00160
2	165036802,1	1	0,00020	0,00180
3	166437966,0	17	0,00340	0,00520
4	167839129,9	40	0,00800	0,01320
5	169240293,7	94	0,01880	0,03200
6	170641457,6	185	0,03700	0,06900
7	172042621,5	324	0,06480	0,13380
8	173443785,4	439	0,08780	0,22160
9	174844949,3	636	0,12720	0,34880
10	176246113,1	720	0,14400	0,49280
11	177647277,0	675	0,13500	0,62780
12	179048440,9	597	0,11940	0,74720
13	180449604,8	482	0,09640	0,84360
14	181850768,6	356	0,07120	0,91480
15	183251932,5	204	0,04080	0,95560
16	184653096,4	123	0,02460	0,98020
17	186054260,3	61	0,01220	0,99240
18	187455424,2	25	0,00500	0,99740
19	188856588,0	9	0,00180	0,99920
20	190257751,9	4	0,00080	1,00000
21	191658915,8	0	0,00000	1,00000

The graphical illustration of results of modeling for $\mathbf{C_{Total}}$ is shown in Figure 12.

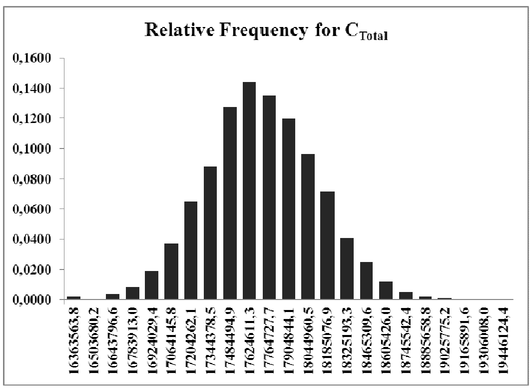

Figure 12: The histogram for $\mathbf{C_{Total}}$

The results of modeling of statistical parameters are shown in Table 7.

Table 7: The results of Modeling: Statistical parameters VaR(5%), VaR(95%), Average and Stdev, LVL

VaR(5%)_C_Total =	170105077
VaR(95%)_C_Total =	182910351
Average(C_Total) =	176413056
StDev(C_Total) =	3934050

Using received information (see Table 7) is possible to define (90%) confidence interval for C_{Total} – (170105077; 182910351). The received results of statistical modeling allow defining expected values of road transport accidents x_1, x_2, x_3 and general economic losses caused by traffic road accidents C_{Total} in Latvia. This information can be base for effective road safety strategy development which make possible to prevent and reduce road traffic crashes and injuries, to optimize decision making process in management of road infrastructure, to implement the recommendations for Latvian government for improving safety on Latvian roads.

CONCLUSION

Road traffic accidents are a growing world social and economic problem. A lot of people killed in traffic accidents are young adults aged between 15 and 44 years (World Report on Road Traffic Injury Prevention). As mentioned above, road traffic injuries cost low-income and middle-income countries between 1% and 3% of their GDP. Road traffic crashes and injuries are preventable. The opportunity of using of statistical modelling for research of road accidents on highways and town's roads of Latvia is presented in this paper.

The application of statistical modelling using Monte Carlo method allows:

- to make analysis of road accidents on highways and in towns and regions of Latvia;
- to predict the possible values of road transport accidents x_1, x_2, x_3 in main roads and populated areas (towns);
- to define economic losses caused by traffic road accidents C_{Total}.
- to analyse the dynamics of changes of road accidents taking into consideration the time factor.

Road traffic accidents prevention must be incorporated into the development and management of road infrastructure.

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INTEGRATED INTELLIGENT PLATFORM FOR MONITORING THE CROSS-BORDER NATURAL-TECHNOLOGICAL SYSTEMS

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ABSTRACT
The paper presents the ongoing INFROM project 'Integrated Intelligent Platform for Monitoring the Cross-Border Natural-Technological Systems', ELRI-184 within the Estonia-Latvia-Russia cross border cooperation Programme within ENPI (European Neighbourhood and Partnership Instrument) 2007-2013. The project aims to improve integrated monitoring and control of cross-border complex systems which contain natural, technological and social elements, in normal and emergency situations based on heterogeneous data received from space and ground-based information sources.

Keywords: integrated monitoring and control, cross-border complex systems, natural, technological and social components.

1. A SHORT SUMMARY OF THE PROJECT

Nowadays, monitoring and control methods are applicable only for specific Natural Technological Systems (NTS). As a result, statistical information about existing systems is not well coordinated. This drawback becomes more evident in emergency situations, when effective decisions must be taken within a short time period while different information flows have to be analysed.

Monitoring information regarding incidents and disasters is received typically from different facilities (e.g. biometric systems, aerospace systems, etc.), and, therefore, it is heterogeneous in nature (e.g. electrical signals, audio and video information, text, etc.). Thus, since modern NTS are very complex and multi-functional objects, their monitoring and control should be performed in conditions of large-scale heterogeneous data sets. Nowadays, the monitoring and control processes of NTS are still not completely automated.

The INFROM project addresses the problem of integrated monitoring and control of cross-border natural-technological systems in normal and emergency situations, based on analysis of heterogeneous data received from both space and ground-based facilities.

The project results will provide a unified approach for integrated monitoring and control of complex systems based 1) on analysis of heterogeneous data received from space and ground-based facilities; and 2) on different types of systems models (i.e., analytical, algorithmic, mixed) used to model behaviour of these systems. In order to select and develop an appropriate model, techniques for estimation of the model quality and its adjustment to a real application, are enrolled.

The INFROM project is an integrated one in which each partner carries out a part of activities of a joint project on its respective side of the border. And, the project priority and measure are defined as common challenges and joint actions aimed at protection of environment and natural resources.

The project is being implemented in close partnership of Riga Technical University (RTU, Latvia) and St. Petersburg Institute for Informatics and Automation of the Russian Academy of Sciences (SPIIRAS, Russia), and with the participation of associate partners, i.e. Committee on IT and Communication government of City of St. Petersburg (Russia), Latvian Transport Development and Education Association, and Diplomatic Economic Club (Latvia). Each project partner has accumulated unique experience and competence to fulfil its specific role in the project.

Key research activities of RTU include modelling and optimization of complex systems using artificial intelligence techniques, simulation in engineering, logistics and industrial management, as well as visualization in simulation. SPIIRAS has reach experiences of developing software and hardware for information real-time processing, developing information technologies for intelligent automation systems of control, developing fundamentals, models and methods aimed at investigating information processes in various complex systems. Besides, the lead partner, Riga Technical University, holds responsibility for the overall project management and administration; implementation of project activities and communication with all project participants, which is going to be established during implementation of the project.

The target groups which are the final beneficiaries of the project are ministries and agencies of regional development; environment, geology and meteorology centres, departments of civil defence and emergency, local authorities, and academic and research staff of universities and research institutions. These institutions will benefit from possibilities to use the innovative intelligent information technology for monitoring and control of NTS structural dynamics (Okhtilev et al. 2006) in both normal and emergency situations. Integration of numerous heterogeneous data sources will unify and simplify the monitoring and control processes. Moreover, the proposed information technology will allow non-professional users to design and develop integrated real-time monitoring and control systems of natural-technological facilities.

2. OBJECTIVES

The overall objective of the project is to develop a universal common intelligent platform for unifying efforts of specialists from Russia and Latvia to protect the environment and natural resources, based on the integrated space-ground monitoring.

Specific objectives of the project include:

- Description of the state-of-the-art in automation and intellectualisation of complex systems monitoring and control in normal and emergency situations considering data from both space and ground-based sources;
- Development of a conceptual framework for intelligent monitoring and control of NTS based on mixed-type data processing;
- Development of IT tools for synthesis of an integrated intelligent platform for the cross-border NTS monitoring and control;
- Development of a software prototype to demonstrate possibilities and advantages of suggested tools for analysis and synthesis of an integrated system for the cross-border NTS monitoring and control;
- Creating a distributed network of workstations to support commercialisation of the project results during and after the project lifecycle.

3. PROJECT SCOPE

The project scope is specified by five Activity Packages (APs): AP1 – Management and Coordination; AP2 – Information and Visibility; AP3 – Information Technology Design and Development; AP4 – Implementation of Integrated Support Tools; and AP5 – Capacity Building.

The first activity package is aimed to ensure an efficient project management and information flows between partners and activity leaders. Traditional project activities such as organising technical meetings, steering committee and advisory board meeting are also in the AP1 scope.

The second activity package provides the project publicity measures and target audience with information about the project opportunities and results. Kick-off, progress and closing conferences are the main activities in the scope of the second activity package.

The third activity package focuses on development of methods for NTS's information representation under conditions of system structure dynamics and data uncertainty (Kokorin et al. 2012) and for NTS integrated modelling and simulation including dynamic reconfiguration of these systems under degradation process of their structures, as well as on development of innovative information technology for analysis and synthesis of an integrated intelligent platform for cross-border NTS monitoring and control. The monitoring and control of NTS will be based on integration of heterogeneous information received from space and ground-based facilities. The above-mentioned tasks will be solved by means of accumulating results of classical control theory, operations research, artificial intelligence, systems theory and systems analysis.

The forth activity package focuses on design of techniques for accumulating and usage of knowledge about NTS states; techniques for analysis and synthesis of NTS monitoring, and control systems considering heterogeneous space and ground-based data, as well as on design of a software prototype for synthesis and intellectualization of NTS monitoring and control technology that is oriented on concurrent on-line user software assurance for different types of space and ground-based monitoring data. This technology is based on flow computing models executed in real-time and in territorially distributed computing networks (Okhtilev and Vasiliev 2004).

The last activity package is centred on approbation of the developed technology platform within existing application domains and capacity building involving external experts and representatives of target groups for analysis and discussion of the project results. Attention will be paid to the growing potential of cooperation between Russia and Latvia and EU at all levels by creation of an international network, including scientific and educational institutions, local government agencies.

Implementation of all activity packages is organised within International Working Groups consisting of researchers and specialists from project partner organisations and external experts.

4. INNOVATIVE APPROACH

The innovative approach to integrated monitoring and control of complex systems including natural, technological, economic and social elements is introduced in the project. This approach supposes (see Fig. 1):

1) Integrated real-time monitoring and control based on analysis of heterogeneous information from space and ground-based facilities;
2) Unified processing environment for processing heterogeneous data from different sources and their integration;
3) Distributed, real-time database embedded into the monitoring and control system for creating a common information space;

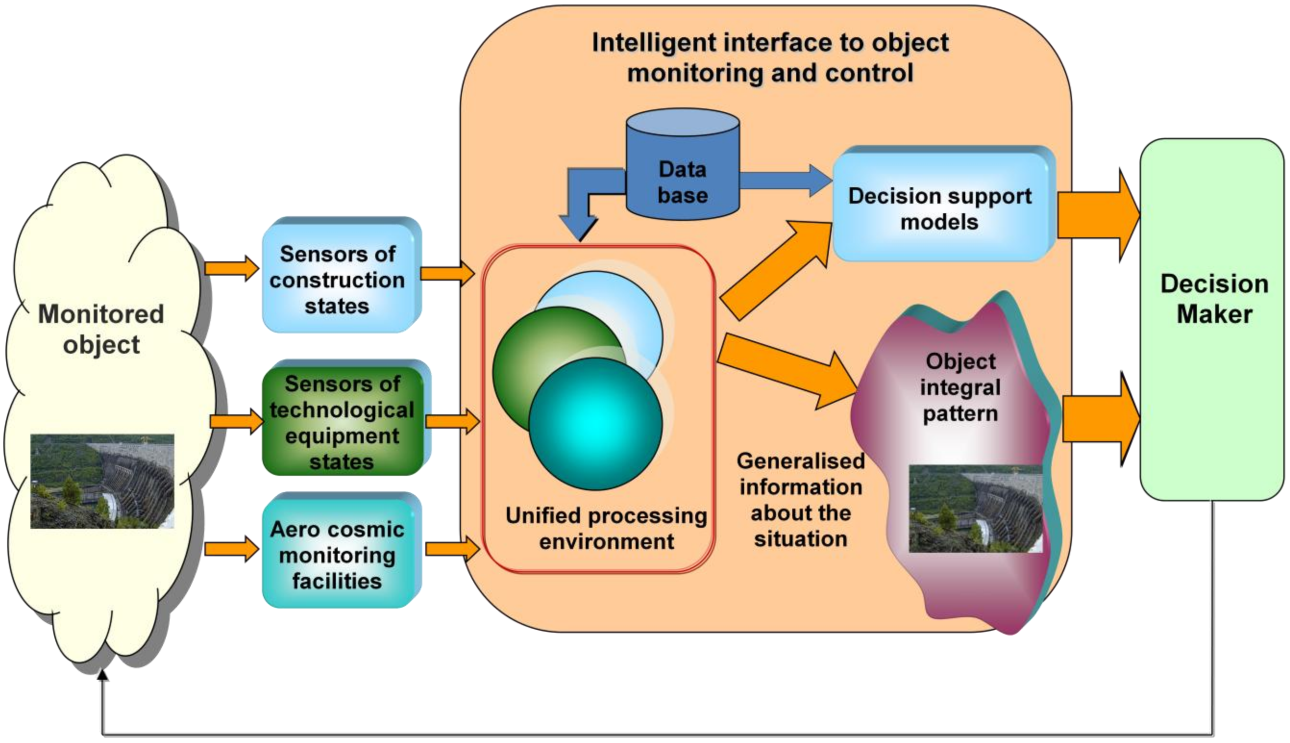

Figure 1: Integrated Monitoring and Control System

4) Multi-models for behaviour analysis of complex objects in normal and emergency situations and decision support.
5) Intelligent interface to object monitoring and control;
6) Data-flow computing models for large-scale datasets executed in real-time and in territorially distributed computer networks.

5. EXPECTED RESULTS

The following results from project implementation are expected:

- Improved monitoring of cross-border natural-technological systems by implementation of an integrated intelligent monitoring and control platform in Latvia and Russia;
- An increased precision of event forecasting for the situation course by using simulation techniques;
- Increased capabilities of specialists by organisation of their training in both Latvia and Russia;
- Intelligent IT tools for NTS monitoring and control considering integrated data from both space and ground-based sources;
- Models of NTS as well as monitoring and control systems in normal and emergency situations;
- Methods of dynamic reconfiguration of NTS monitoring and control systems;
- Techniques for synthesis of intelligent NTS monitoring and control systems considering heterogeneous space and ground-based data;
- A software prototype for NTS monitoring and control based on heterogeneous space and ground-based data;
- An integrated distributed network of workstations to provide a remote access to data archives and their integrated processing in Latvia and Russia.

6. SUSTAINABILITY OF PROJECT RESULTS AFTER THE PROJECT LIFE CYCLE

Sustainability of project results after the project life cycle is defined by a high level of their topicality for various natural and technological systems in different problem areas, as well as by an innovative nature of project developments.

The project will contribute to sustainable development of the cross-border region environment. Environmental sustainability will be ensured by providing an integrated intelligent platform and related intelligent information technology for efficient monitoring and control of NTS in normal and emergency situations providing a higher level of the ecological safety. Also, the elaborated GIS (geographical information system) prototype is aimed to support an Internet-based customer service system by receiving and processing heterogeneous space and ground-based data within the cross-border regions for control of monitoring objects. The developed customer service system will provide integrated monitoring and control facilities and an intelligent interface with them suitable for non-professional users. The sustainability of project results after its completion will be also secured by scalability and flexibility of the developed intelligent platform providing possibilities to replicate and extend the implemented functionalities. Moreover, the implemented information network of workstations will provide a unified information and intellectual space for cross-border communication at different levels. Additionally, planned within the project training activities will allow capacity building for providing the sustainability of project results after the project life cycle.

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ANALYSIS OF THE OPERATIONS OF AN INTERMODAL BARGE TERMINAL

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ABSTRACT
This paper studies the operations of intermodal barge terminals. The objective is to increase the terminal's efficiency by supporting the operational planning of the terminal operator. For this purpose a review on general and process specific barge terminal planning problems, discussed in current scientific literature, is provided. This theoretical knowledge is verified in practice by means of a comparison with operational planning realities at Haven Genk, a Belgian trimodal terminal. Finally, a simulation study based on Haven Genk data is performed to investigate whether vessel size and number of vessels in use have an impact on barge terminal efficiency.

Keywords: barge terminal, operational planning, discrete event simulation

1. INTRODUCTION
During the last decades, the quality of freight transport experiences an increasing pressure. The huge growth in and the dominant role played by road transport have caused a wide variety of problems. These problems induce a decline in the reliability of freight transport and an increase in customers' lead time. In addition, policy makers realise that the negative impacts of this type of transportation on nature and the environment need to be stopped (Konings et al. 2006).

A shift from freight transport by road to intermodal transportation is an opportunity to meet the need for an efficient and environmentally friendly transport mode. Intermodal transportation means that the main transport is performed by alternative transport modes like rail, barge or sea, while the secondary pre- and post-transport goes by road and is as short as possible (Macharis and Verbeke 1999). In intermodal transport a central role is played by terminals which take care of the transhipment of freight from one transportation mode to another. However, operations cost of intermodal terminals constitutes an important cost element in intermodal transportation, which reduces its competitive strength against unimodal road transport. For this reason, it is essential to ensure that intermodal terminals work as efficient and effective as possible. Minimising container throughput time and reducing transhipment costs may lead to reinforced market power for the intermodal transport sector, improving chances for a modal shift.

To determine how operational costs of transhipment terminals may be reduced, it is necessary to perform a thorough study of its operations. In this way, opportunities for improvement may be traced and operational efficiency of intermodal terminals may be enhanced. This paper focuses on barge terminals, which perform transhipment between road and barge transportation.

The remainder of this paper is organised as follows. Section 2 provides a review of the various planning problems a barge terminal operator can be confronted with on different organisational and temporal levels. Section 3 describes the operational planning reality at Haven Genk, a Belgian trimodal terminal, and compares it to the theoretical knowledge described in section 2. Section 4 discusses the design and computational results of a simulation study, based on Haven Genk data. This study aims to identify the impact of vessel size and number of vessels in use on general terminal efficiency. Finally, section 5 formulates conclusions and possible directions for future research.

2. PLANNING PROBLEMS OF A BARGE TERMINAL OPERATOR
The main task of a terminal operator consists of ensuring a smooth operation of the container transhipment process in order to reduce the operational costs and increase the competitiveness of the terminal.

In a barge terminal, five subprocesses may be distinguished in the transhipment of containers. First, the vessel arrives at the terminal and moors at a specific berth. Freight containers need to be loaded and unloaded from the vessel making use of quay cranes. Next, the unloaded containers are transferred to stacks, which are covered or uncovered terminal areas where containers can be stored for a certain amount of time. Finally, containers are retrieved from their stacks and transported to other transport modes like trucks, trains or vessels to complete their journey to the final customer (Vis and de Koster 2003).

The efficiency with which these subprocesses are executed is greatly determined by the way the terminal operator handles planning problems associated with them. Caris et al. (2008) make a distinction between three temporal levels of planning related to the functioning of a transhipment terminal. The strategic level considers long term planning (ten to twenty years) and involves the highest management level as it concerns large capital investments over long time horizons. On a medium time level (months or weeks), tactical planning arises with the purpose of enhancing the general system performance through ensuring an efficient and rational resource allocation. Finally, short term (daily or real-time), operational planning involves decisions in a highly dynamic environment made by local management.

Taking into account the above factors associated with terminal operator planning, two classification matrices can be created for his operational problems. In general, a distinction can be made between two problem categories, coinciding with two different matrices. On the one hand, the terminal operator is confronted with various general planning problems on the three temporal levels associated with the transhipment terminal. On the other hand, specific planning problems linked to the different subprocesses in container transhipment can be identified, again on the strategic, tactical and operational levels. Both matrices, presented in Tables 4 and 5 which can be found in Appendices A and B respectively, will be briefly described in the following paragraphs.

2.1. General terminal operator planning problems

The first category of planning problems constitutes challenges which are not exclusively associated with barge terminals. Table 4 presents an overview of these problems, based on the articles by Caris et al. (2008) and Macharis and Bontekoning (2004).

On a **strategic level**, the terminal operator needs to decide on the design of his intermodal terminal. Design decisions concern, among others, the type and capacity of terminal facilities, the general way of employing material and labor in the transhipment process and the overall lay-out of the terminal (Macharis and Bontekoning 2004). When making a terminal design choice, the operator can opt for an own design adapted to his specific intermodal needs or a design suggested in scientific literature with a record of proven performance. In any case, the decision needs to be well-considered as the final design has a significant impact on the efficiency with which a container goes through the different transhipment subprocesses.

Concerning **tactical planning**, a terminal operator has two important tasks. First, he needs to determine the required capacity levels of material and labor resources, a decision which can be made separate from or together with the identification of the appropriate terminal design. A second tactical planning problem is twofold and consists of the design of operational routines, like operating strategies for quay cranes, on the one hand and the determination of specific terminal layout structures on the other hand.

Finally, on the **operational level**, the terminal operator needs to decide how terminal resources (material and labour) will be allocated to the different tasks that need to be performed. More specifically, it concerns the planning of which material infrastructure and number of employees are to be assigned to a certain sequence of labour shifts (Zaffalon et al. 1998). Secondly, the terminal operator has to establish a daily planning of terminal jobs which maximises operational efficiency.

2.1.1. Solution approaches

Reviewing current scientific literature on general terminal operator planning problems, a distinction may be made between optimisation techniques on the one hand and simulation studies on the other hand.

These two distinct solution procedures may also be associated with specific temporal problem levels. As such, it turns out that simulation is the most applied method to solve the strategic problem of terminal design (e.g. Ferreira and Sigut 1995; Rizolli et al. 2002). The choice might be explained because simulation provides the opportunity to model the entire terminal and handle several design issues simultaneously. When solving a tactical problem, the use of simulation versus optimisation techniques may be equally divided (e.g. Kim et al. 2008; Martinez et al. 2004). The choice of solution procedure depends on the preferences of the terminal operator and the distinct characteristics of the terminal. Finally, when looking at operational decisions, the majority of scientific articles suggests the use of optimisation techniques (e.g. Gambardella et al. 2001; Kim et al. 2004).

2.1.2. Performance measures

Besides used solution methods, a distinction may also be made between three general categories of performance measures suggested in current literature on general terminal operator planning problems.

A first category is associated with time. Frequently mentioned time measures within the scope of terminal operator planning problems include: total time needed for (un)loading containers, service times or waiting times of trains/trucks/vessels and total container throughput time. Costs make up a second group of performance measures. Important cost factors associated with terminal operator planning include: crane working costs, transportation costs, container handling costs and labour costs. A final performance measure regularly used to evaluate the efficiency of terminal operations relates to the utilisation of resources (cranes, vehicles, stack locations…).

2.2. Planning problems per subprocess

A barge terminal operator is confronted with several planning difficulties in the various subprocesses of container transhipment. These are presented in Table 5, an outline based on the article by Vis and de Koster (2003).

A first decision that the terminal operator needs to make in the context of a loaded **vessel arrival** on a strategic level is the identification of the number of available berths. For this purpose, a trade-off needs to be made between the investment in additional berths and longer waiting times for arriving vessels (Alattar et al. 2006). Once the terminal operator has decided on the number of berths, he has to allocate arriving vessels to these berths on a daily level.

In a next phase, **containers** need to be **(un)loaded from the moored vessel**. Strategically, the terminal operator has to decide on the type of material to use for this task. Vis and de Koster (2003) state that quay cranes are the most commonly used equipment for the (un)loading job. On a tactical level, the operator needs to determine how many cranes will be employed simultaneously to (un)load a single vessel. As Vis and de Koster (2003) suggest, it is important to perform the (un)loading task as fast as possible in order to minimise waiting times of vessels and comply with the service required by customers. Then, on an operational basis, the terminal operator has to create a detailed (un)loading plan which specifies the precise (un)loading sequence of containers, next to each container's specific position on the vessel (Shields 1984).

When containers are unloaded from the vessel, they need to be **transported from vessel to stack** to be stored there for a certain amount of time. A strategic decision, similar to the one in the (un)loading subprocess, is the determination of the type of vehicles to be used for internal container transport. Possible alternatives the terminal operator can choose from include straddle carriers, forklift trucks, yard trucks or any kind of automated guided vehicle (Vis and de Koster 2003). Once the appropriate vehicles are chosen, the terminal operator needs to identify the necessary number of these transportation vehicles on a tactical level. Finally, on a daily basis, he has to establish a detailed container transport plan. This plan defines which vehicle transports which container and which routes are chosen for this internal transport. These problems can be classified as routing and scheduling problems.

Arriving at the stack, **containers** need to be **stored** for a certain amount of time. The stack may be divided in various blocks or lanes each consisting of a number of container rows. The height of the stack varies according to the available facilities at the terminal (Vis and de Koster 2003). On a strategic level, analogue with the previous phases, a decision needs to be made on the materials used for container stacking. Facilities like forklift trucks, reach stackers, yard cranes and straddle carriers are most commonly used in practice for this job. Next, the terminal operator has to think strategically about the best strategy to stack the containers. This should be a well thought through decision since the way containers are stacked has a significant impact on the efficiency of the following phases of transhipment. A decision associated with the stacking strategy is the determination of the optimal stack configuration. A trade-off should be made between minimal container handling and an optimal use of available stacking space (Decastilho and Daganzo 1993). On a tactical level of the stacking process, the terminal operator has to determine how many cranes or straddle carriers are needed to ensure efficient stacking. On an operational level, the detailed route of container stacking facilities throughout the stack needs to be planned. This plan describes the sequence of lanes the stacking vehicle follows and the number of containers stored in each lane (Kim and Kim 1997).

In the last phase of the transhipment process, containers are **transported from the stack to other transport modes** like train, truck or vessel. Strategically, the operator has to decide on vehicles used for this transport. In this context, Vis and de Koster (2003) suggest employing multi-trailer systems or automated guided vehicles. The terminal operator may also choose to perform this type of transport with the same infrastructure used for the (un)loading subprocess. A trade-off has to be made between making additional investments or accruing additional vehicle waiting times.

2.2.1. Solution approaches

Also for planning problems per subprocess a distinction may be made between the use of optimisation techniques and simulation studies. However, the use of simulation is much less evident in this context. Simulation may be used in combination with optimisation techniques to validate the generated solutions.

When looking in detail at optimisation techniques to solve the various planning problems per subprocess, it appears that the majority of scientific papers suggests the combination of two methods. In many cases, the planning problem is formally modelled and defined as a specific mathematical programming problem which is then solved with an appropriate (meta)heuristic (e.g. Kozan and Preston 1999; Sammarra et al. 2007).

2.2.2. Performance measures

A distinction may be made between three categories of performance measures giving an indication of terminal efficiency.

A first category of measures is associated with time. Important time elements that may be linked with transhipment planning are: waiting or service times of vessels/containers, amount of idle time of cranes/container transport vehicles, (un)loading time and container vehicle travel time. A second category of performance measures are those related to costs. Frequently mentioned cost measures within the scope of terminal operator planning problems are: general waiting costs and fixed or variable costs associated with cranes or container transport vehicles. Finally, some other measures regularly used to evaluate the transhipment process are: utilisation of quays/cranes/vehicles/stack locations, service priorities related to vessels/containers, barge stability, number of container movements and vehicle travel distance.

3. A BARGE TERMINAL IN PRACTICE: HAVEN GENK N.V.

In order to verify the findings from the literature review described in section 2, the general operations of the trimodal terminal Haven Genk N.V., lying in the hinterland of the Port of Antwerp, have been observed for several days. Haven Genk N.V. is a strategically located and fully equipped trimodal terminal performing not only traditional transport and transhipment activities, but also offering its customers additional services like stuffing, stripping and forwarding activities (Haven Genk 2012).

Through the combination of real terminal information, acquired via observation and employee testimonies, and conclusions drawn from current scientific literature, knowledge on barge terminal operations could be significantly refined and deepened. The remainder of this section is organised as follows. In a first paragraph, the main characteristics of Haven Genk's barge planning are explained. Secondly, a direct link is made between the theoretical planning problems found in the classification matrices and operational reality at the trimodal terminal of Genk.

3.1. Barge planning at Haven Genk

Haven Genk mainly transports containers to the Port of Antwerp according to a fixed service schedule of four departures every week. For this transport, Haven Genk may choose to use its own vessel, use a vessel owned by a partner organisation or hire a section on a vessel owned by a broker company.

Two important factors are influencing the barge planning at Haven Genk. First, scheduling of barge container transport is customer driven. When a customer submits a request to transport a certain amount of containers, Haven Genk compares the offers of various shipping companies and chooses the appropriate one according to measures of time or price, depending on the required customer service level. Second, barge planning at Haven Genk strongly depends on decisions made by sea terminal operators at the Port of Antwerp. Haven Genk needs to make separate appointments with these operators, owning several quays at the Port of Antwerp, if it wants a vessel to moor at one of these quays during a specific time slot. Requests to moor need to be submitted at least two days before barge arrival and the seaport terminal operators have the final say in the approval.

3.2. Comparison between theory and practice

This section links the literature review concerning terminal operator planning problems to the way these challenges are handled in real-life at Haven Genk. The goal is to identify possible gaps and overlaps which may point at improvement opportunities in the operations of intermodal barge terminals.

Concerning this comparison, some general remarks may be made. First, not all planning problems mentioned in the classification matrices are handled again in this paragraph. The reason for this fact is that not all planning problems suggested in literature are considered of equal importance in practice. Some planning issues are handled in an automatic fashion at Haven Genk without much thought or modelling work. An example of such a routine practical planning problem is the operational routing and scheduling of container transport vehicles. These routing decisions are taken ad hoc by the vehicle operators themselves on the basis of their experience and intuition. Second, from the employee testimonies and observation results at Haven Genk, it became clear that, in reality, barge planning is scarcely supported by scientific models and methods. More than once, employees emphasised that all decisions need to be made in a dynamic context. It is difficult to create appropriate theoretical models as these cannot account for the various internal and external situations the terminal may be confronted with. For these reasons, improvisation and continuous reflection are two concepts Haven Genk strongly beliefs in.

3.2.1. General terminal operator planning problems

Considering **terminal design** in practice, the general terminal lay-out evolves on the basis of projects, always taking into account available terminal space. On the contrary, literature suggests the use of theoretical models to determine the optimal location of facilities. A possible explanation for this difference is the fact that models suggested in literature are developed for terminals focusing exclusively on container transhipment. Therefore, the design of Haven Genk, a trimodal terminal offering an entire set of logistical services, cannot be handled this straightforward and will eventually develop depending on projects and contracts the terminal engages in.

On a tactical level, the terminal operator needs to decide on **capacity levels**. The performance measure Haven Genk focuses on when taking this decision is the processed container volume at the terminal. The terminal operator monitors whether the terminal has sufficient material and labour capacity at its disposal to handle the requested demand volume. Only when the benefits of transporting containers using own resources can compensate for additional investments, the terminal operator will decide to acquire additional infrastructure. This statement may be proved with the fact that Haven Genk has reduced its vessel fleet in 2010 to a single vessel as a consequence of the strong decline in barge transport volumes. Comparing this volume based approach with the theoretical solutions to capacity identification as suggested in scientific literature, it may be noted that the use of theoretical models to decide on capacity levels is justified only when transport volume is sufficiently high.

3.2.2. Planning problems per subprocess

In practice, the entire process of container transhipment from arrival of the vessel to transportation of containers to other transport modes is strongly customer driven. The customer determines the required service level and as such the performance measures Haven Genk has to take into account in the planning of container transhipment. Secondly, the trimodal terminal is rather dependent on the Port of Antwerp for the establishment of its barge planning. This dependence has an impact on the way the trimodal terminal approaches its transhipment process. Finally, waiting time appears to be a crucial performance measure for Haven Genk in all of the transhipment phases. It is therefore of key importance to organise and perform all of the subprocesses as efficient as possible in order to reduce these waiting times and their associated costs to a minimum.

Considering the **arrival of vessels** at the terminal, an operational decision relevant in the context of the trimodal terminal is the allocation of these barges to the available berths. As Haven Genk has only one quay at its disposal, this planning problem is not an issue. However, terminal operators at the Port of Antwerp need to make this decision. When Haven Genk contacts them to (un)load a certain amount of containers, they have to decide which quay is most suited for this job. This decision depends on the shipping company taking care of the container transport. Additionally, they also take into account the sequence in which containers need to be (un)loaded so as to minimise waiting times. This practical approach to vessel allocation has some important overlaps with solution methods suggested in scientific literature. First, waiting time is considered an important performance measure both in practice and in theory. Theoretical models and practical allocations both strive to minimise the time a vessel spends at a terminal. Second, vessel allocation is often a customer driven decision. This customer focus is expressed in literature through the use of service priorities, while Haven Genk mainly looks at customer provided time windows to (un)load a vessel.

A strategic decision related to almost all subprocesses is the choice of appropriate infrastructure to perform the respective transhipment task. Concerning the **loading and unloading of a vessel**, Haven Genk has two quay cranes at its disposal, mainly used for (un)loading containers. In addition, the terminal has three hydraulic cranes and three bulldozers to load and unload bulk cargo. On an operational level, the terminal operator has to establish a container load plan which specifies the sequence in which containers are loaded and unloaded from the vessel. This plan is strongly influenced by the time windows and quays Haven Genk is assigned to by sea terminal operators in the Port of Antwerp. The specific location of a container on the vessel is a decision made by the captain of the vessel, as opposed to what is suggested in scientific literature.

Then, containers need to be **transported to the stack** where they are stored for a certain time period. Haven Genk employs reach stackers to perform this internal container transport. These vehicles can stack containers up to five rows high, as opposed to straddle carriers, which can only stack containers up to two high.

Next, Haven Genk **stacks containers** on the basis of their characteristics. Containers are grouped in stack lanes on the basis of their destination, the quay they need to be unloaded on or the shipping company taking care of their further transportation. The goal of this stacking strategy is to minimise container rehandling during their loading on another transport mode.

4. SIMULATION STUDY

4.1. Introduction

Combining our findings from literature with the observations at Haven Genk leads to the conclusion that it is essential to approach the various terminal operator planning problems as careful and well-considered as possible in order to guarantee optimal functioning of the terminal. Concerning the solution methods to these planning problems, theory and practice suggest a wide variety of procedures. Simulation is a technique often used in the context of container terminals. As defined by Hassan (1993), simulation is a scientific methodology to study a complex environment like a multimodal terminal.

Simulation of the transhipment process of containers in a barge terminal is an effective method to study the various planning problems terminal operators are challenged with in this context. Simulation creates the opportunity to study the efficiency of the various transhipment subprocesses under varying conditions using a simplified terminal model. In addition, it becomes possible to define the factors influencing terminal operations in an artificial reality. The processes in a container terminal may be reviewed without accruing high costs or making permanent changes to the current terminal. Moreover the various planning problems on all temporal levels (strategic, tactical and operational) may be studied simultaneously and scenarios may be developed to answer ‘what-if’ questions concerning transhipment planning (Nomden 2007).

The purpose of the following paragraphs is to apply discrete event simulation to the barge terminal of Haven Genk. Section 4.2 briefly describes the translation of the Haven Genk barge terminal operations into a simulation model fit for Arena software. Next, section 4.3 develops various simulation scenarios concerning used materials or infrastructure and processed container volumes on the basis of theoretical findings and practical suggestions. The goal is to examine whether adaptations in vessel sizes and number of used vessels have an impact on terminal efficiency under various container volumes. Replication parameters and studied performance measures are outlined in section 4.4.. Finally, section 4.5 describes the main results of the simulation study and formulates recommendations to Haven Genk in order to improve its transhipment efficiency and its anticipation capability to changing container volumes.

The simulation study described in the following subsections proposes a first, simplified implementation of the barge terminal operations at Haven Genk. However, the suggested model may provide an incentive for future refined simulation applications as described in the 'future research' paragraph of section 5.

4.2. Simulation model: Haven Genk barge terminal

The operations of the Haven Genk barge terminal may be described by means of the different phases a container goes through in the transhipment process. For export containers, which reach the terminal by truck or via rail and leave the terminal by barge, the following steps may be distinguished. When the container arrives at the terminal via the landside, it is identified through the registration of data like container content, destination, shipment company and barge to be loaded on. In a next phase, the container is transported with the use of a reach stacker to the appropriate lane in the stack. Finally, when the container's destination vessel has arrived, it is retrieved from the stack and loaded on this vessel to continue its journey to its destination. The phases in the transhipment process of an import container, reaching the terminal by barge and leaving it via the landside, are similar to those of an export container but in reverse order. Both processes run simultaneously in every barge terminal (Günther and Kim 2006).

The Arena flow diagram in Appendix C represents the different phases of transhipping an import container, starting with the arrival of the loaded vessel at the terminal and ending with the container pursuing its trajectory over land. Its various building blocks associated with the different transhipment phases will be described below. Containers are considered as the entities in the system.

The first four blocks of the diagram represent the arrival of import containers at the terminal by barge. Container arrival times, based on real Haven Genk data, are read from a Microsoft Excel file. Next, the created container entities are unloaded from their respective vessels. For this purpose, a Process module is used which represents a quay crane seizing a container and releasing it after some time in the stack zone. Since the length of time spent in the stack differs for full and empty containers, a Decide module is inserted to make sure that 78% of all stacked import containers are full and 22% are empty. After a certain time period the appropriate containers are loaded onto their respective landside transport modes like trucks or trains making use of a reach stacker. Finally, the import containers leave the system to pursue their trajectory over land to the end customer. The transhipment of export containers, starting with the arrival of containers at the terminal by train or truck and ending with leaving the terminal by barge, can be described and modelled in a similar, but reversed, way.

The main **assumptions or inputs** applicable in both parallel, simultaneous transhipment processes are the following. At first, assumptions made for the *import container transhipment process* are described. To start with, an arrival rate needs to be determined for vessels unloading their import containers at the barge terminal. For this task, Haven Genk disposes of two 154 TEU vessels each arriving two times a week at the barge terminal. These vessels are used in cooperation with the transhipment terminal of Liège to an average capacity of 104 TEU, meaning that containers are stacked in two rows. The remaining 50 TEU, corresponding to a third layer of containers, is used as a buffer to cope with demand peaks. An annual average of 12500 TEU can be allocated both to the transhipment process of import containers and to the transhipment process of export containers, which corresponds to 240 TEU weekly or 60 TEU every arrival day. This amount of 60 TEU is considerably lower than the 104 TEU vessel capacity. An explanation for this difference is that the remaining space on the barge is used by containers from the Liège terminal. Secondly, a distribution has to be determined for the import container unloading time. In this context, Haven Genk stated that quay cranes are capable of unloading 17 containers in one hour. Next, in the stacking Process modules for full and empty containers a distribution needs to be identified for the time containers spend in the stack. Based on Haven Genk information, a Triangular Delay Type is chosen here with minimal, modal and maximal values for the stacking times of full and empty containers respectively. Finally, import containers are loaded on trucks or trains making use of reach stackers. Similar to the unloading process, a Constant Delay Type is chosen here, now with an average value of 2.86 minutes since reach stackers are more flexible than quay cranes. An additional assumption made in the context of *export container transhipment* is the determination of the arrival rates of trucks and trains transporting containers to the barge terminal via the landside. As already mentioned above, an export container volume of 240 TEU is processed every week at the terminal. Considering the fact that trucks and trains transport containers to Genk every workday, an average of 48 TEU can be allocated to Monday, Tuesday, Wednesday, Thursday and Friday.

4.3. Simulation scenarios

For the purpose of analysing barge terminal efficiency under various circumstances, three general scenarios with different vessel sizes and number of available vessels are created. In addition, for each of these scenarios an optimistic and pessimistic subscenario is considered regarding the processed container volume.

4.3.1. Baseline scenario

The baseline scenario corresponds to the current situation of Haven Genk. Barge transport is performed by two vessels of 154 TEU each, of which 104 TEU is used effectively to stack containers and 50 TEU serves as a buffer against demand fluctuations. Concerning container volume, Haven Genk processes 25000 TEU annually meaning that a weekly average of 240 TEU can be allocated to import containers and export containers respectively. The other inputs of this scenario are described in paragraph 4.2..

In an optimistic subscenario the current vessel fleet is kept unchanged, while the processed container volume increases to 40000 TEU annually, a rise of 60% with regard to its current level. This choice of 40000 TEU is based on Haven Genk data concerning expected future developments in barge transport container volumes. In a pessimistic scenario, again maintaining the current fleet size, a decline of the processed container volume to 20000 TEU (-20%) is considered.

4.3.2. Scenario A

In this scenario one of the 154 TEU vessels is replaced by two 60 TEU vessels. In this way, the terminal has three vessels at its disposal to transport containers by barge. The current annual container volume of 25000 TEU remains unchanged. The only simulation input changes needed to run this scenario pertain to the arrival rates of containers. Considering import containers, the availability of three vessels creates the opportunity to provide customers with a service of six departures every week instead of the current level of four. This leads to the following weekly barge planning for Haven Genk:

Table 1: Barge Planning Import Containers Scenario A

Day of the week	Arriving vessel size	Loaded TEU volume
Monday	104 TEU	55 TEU
Tuesday	60 TEU	33 TEU
Wednesday	60 TEU	33 TEU
Thursday	104 TEU	55 TEU
Friday	60 TEU	32 TEU
Saturday	60 TEU	32 TEU

Regarding this barge planning, barge utilisation is significantly lower than its capacity level. The explanation for this fact is that the remaining vessel stacking space is used by containers transported by the Liège terminal working in cooperation with Genk.

In an optimistic subscenario the three vessels of scenario A are maintained, while the processed container volume increases to 40000 TEU annually. This leads to the conclusion that, as a consequence of the increased container volume, the 60 TEU vessels can no longer be used in cooperation with the Liège terminal. In addition, the average utilisation of the 154 TEU vessel is now raised to the total 154 TEU, thus losing the buffer, in order to make cooperation and sharing of costs for this vessel still possible. In a pessimistic scenario, maintaining the fleet size of three, a reduction of the processed container volume to 20000 TEU is considered.

4.3.3. Scenario B

In this scenario one of the 154 TEU barges is replaced by only one 60 TEU barge to find out if this limited fleet size can cope with various container volumes. The current annual container volume of 25000 TEU remains unchanged. The only simulation input changes needed to run this scenario pertain to the arrival rates of import containers. As the terminal disposes of two vessels like in the basic scenario, a service of four departures every week can be provided to customers. This situation leads to a four day allocation of 60 TEU container volume. As a consequence, the 60 TEU vessel cannot be operated in cooperation with the Liège terminal as Haven Genk will need the entire barge stacking space to cope with current customer demand.

In an optimistic subscenario both vessels of scenario B are maintained, while the processed container volume increases to 40000 TEU annually. This leads to the conclusion that, as a consequence of the increased container volume, neither the 60 TEU barge nor the 154 TEU barge can be used in cooperation with the Liège terminal. In addition, the average utilisation of the 154 TEU vessel is now raised to the total 154 TEU, thus losing the buffer, to cope with the rising demand level. In a pessimistic scenario, maintaining the fleet size of two, a reduction of the processed container volume to 20000 TEU is considered.

4.4. Replication parameters and performance measures

To obtain a sufficiently realistic picture of the actual functioning of a barge terminal and to guarantee stable simulation results, it is necessary to run the study over a significant period of time, in this case over a period of 10 weeks. Each week is simulated separately, accounting for the number of remaining containers from the previous week, and can thus be considered a single model replication with a replication length of 7 days. In this way, simulation results can be compared over a period of 10 weeks and it becomes possible to draw realistic conclusions regarding the values of performance measures in each of the simulation scenarios.

The performance measures to determine the effect of varying vessel types, fleet sizes and container volumes on the general barge terminal efficiency are the following. First, the utilisation rates of the resources quay crane, reach stacker and stack locations are examined. Next, the total container throughput time and its time spent in the various subprocesses of transhipment is investigated. Finally, a trade-off is made between customer service, in terms of vessel departure frequency, and the costs of employing the available vessel fleet.

4.5. Main simulation results and discussion

This paragraph describes the main results of simulation analyses performed on the three scenarios and formulates some recommendations to Haven Genk concerning used vessel sizes and number of vessels to ensure optimal barge terminal functioning.

4.5.1. Simulation results

The main simulation results are presented in Table 2. First, it can be concluded that the relevant performance measures ‘resource utilisation’ and ‘container throughput time’ are not significantly influenced by the fleet changes. Secondly, analysing the effects of positive and negative container volume changes demonstrate that resource utilisation is affected in a linear way by the processed volume. For example, the utilisation degree of both quay cranes and reach stackers increases with 60% when the container volume rises with the same percentage in all three studied scenarios. On the contrary, the terminal efficiency measure of container throughput time remains unchanged under varying container volumes.

Table 2: Main Simulation Results

	Resource utilisation		**Container throughput time**
	Quay crane	Reach stacker	
Basic scenario	17%	14%	70 hours
Basic scenario opt	27%	22%	70 hours
Basic scenario pess	14%	11%	70 hours
Scenario A	17%	14%	70 hours
Scenario A opt	27%	22%	70 hours
Scenario A pess	14%	11%	70 hours
Scenario B	17%	14%	70 hours
Scenario B opt	27%	22%	70 hours
Scenario B pess	14%	11%	70 hours

Additionally some general remarks may be made for the simulation analysis outcomes. First, concerning the utilisation of stack locations, results show that they are significantly lower than the available capacity of 20000 TEU. The explanation for this outcome is that the simulation model only accounts for containers transported by barge. The numerous containers transported by truck or train only, which are also temporary stored in the stack, are not included in our model. Second, the resources ‘quay crane’ and ‘reach stacker’ are underused with utilisation degrees under 30%. For the reach stacker the explanation may be found again in the simplifications made in this simulation study. Since Haven Genk in reality uses the reach stacker for other purposes than container transhipment, it can be expected that the simulation utilisation degree is below the realistic level. The low utilisation of the quay crane cannot be explained, since Haven Genk uses this resource exclusively for (un)loading vessels and all containers transported by barge were included in the model. Finally, from the analysis of the container throughput time, it turns out that more than 90% is due to one subprocess in container transhipment, namely container storage in the stack. Time spent in the stack has a significant impact on general terminal efficiency.

4.5.2. Recommendations to Haven Genk

Considering the fact that the applied vessel changes appeared to have no significant influence on the barge terminal efficiency in terms of container throughput time and resource utilisation, Haven Genk may be advised to focus on the service-cost relation when deciding on available fleet sizes. Comparing this relation for the three scenario’s (Table 3), the following recommendations can be formulated. If Haven Genk opts for a reinforcement of its customer focus, the terminal operator can choose to replace one 104 TEU vessel with two 60 TEU vessels (scenario A) as this leads to a 50% rise in service level. However, this service level increase is also associated with a 42.5% rise in costs. Accordingly, when the service level increase of 50% cannot produce sufficient returns to compensate for those increased costs, it is best to relinquish scenario A. In that case, Haven Genk should execute scenario B to acquire the best results since this scenario preserves the current service level without any efficiency losses while costs diminish with 4%.

Table 3: Service-Cost Relation in Three Scenarios

	Service level	**Cost level (weekly vessel cost + fuel cost)**
Basic scenario	4 departures/week	€24092
Scenario A	6 departures/week	€34338
Scenario B	4 departures/week	€23192

Regarding the low utilisation level of the quay crane, it is best Haven Genk performs a thorough investigation to find out its cause in order to ensure terminal efficiency. Finally, since the container throughput time mainly consists of time spent in the stack, Haven Genk should focus on reducing storage times when working towards lower container transhipment times.

5. CONCLUSIONS AND FUTURE RESEARCH

To reinforce the competitive strength of intermodal transportation in its strife against unimodal road transport, it is essential to organise terminal operations as efficient and effective as possible. Investigating the operations of intermodal barge terminals in theory and practice is therefore the central research question in this paper.

From a thorough review of current barge terminal literature, it became clear that the terminal operator’s approach to the various planning problems in container transhipment has a significant impact on terminal cost and time levels. A comparison of literature findings with the operations at Haven Genk, a Belgian trimodal terminal, leads to the conclusion that not all theoretic planning problems are considered equally relevant in practice. In addition, it became clear that barge planning could be supported with theoretical models only in a limited way as terminals operate in a very dynamic environment where improvisation and continuous reflection are important concepts. Finally, a simulation study was developed to investigate whether variations in vessel sizes, fleet sizes and container volumes had a significant effect on terminal efficiency. An analysis of the simulation results showed that the relevant performance measures were not significantly affected by the applied fleet size changes. As a consequence, Haven Genk focuses best on service-cost relations when deciding on used vessel types. In addition, it turned out that changing container volumes influenced resource utilisation in a linear way and container throughput time is mainly caused by the stacking subprocess.

The study on terminal operations described in this paper leaves some opportunities for future research. A first opportunity is to investigate the planning problems other transportation network actors, like drayage, network and intermodal operators, are confronted with. Secondly, when exploring barge terminal operations, the focus may be expanded from considering container transhipment exclusively to accounting for additional services like bulk transhipment, stuffing and stripping services or forwarding activities. It could be useful to explore whether these additional tasks have a significant impact on terminal efficiency. Moreover, besides barge transhipment operations also truck and train transhipment could be included. Finally, as the simulation study showed that the applied vessel changes did not influence performance measures considerably, another possible direction for future research could be to create additional simulation scenarios. These scenarios could contain modifications in number of used quay cranes/reach stackers or in terminal lay-out. Considering Haven Genk's relationship with the Port of Antwerp another possibility is to create coordination/dependency scenarios integrating both actors. Finally, it could be useful to perform a sensitivity analysis to find out in which cost ranges (fixed vessel costs and fuel costs) the current advices on fleet sizes remain valid.

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APPENDICES

Appendix A

Table 4: General Terminal Operator Planning Problems

Time horizon		
Strategic	**Tactical**	**Operational**
Terminal design	Identification of material and labour capacity levels	Resource allocation
	Design of operational routines and layout structures	Job scheduling

Appendix B

Table 5: Terminal Operator Planning Problems per Subprocess

Subprocess in transshipment	Time horizon		
	Strategic	**Tactical**	**Operational**
Arrival of the vessel	Identification of number of needed berths		Allocation of vessels to berths
(Un)loading of the vessel	Selection type of material for (un)loading	Identification of optimal number of quay cranes	Establishing appropriate load plan
Transport of containers to stack	Selection type of material for transport	Identification of optimal number of container transport vehicles	Establishing container transport planning
Stacking containers	Selection type of material for stacking	Identification of optimal number of transfer cranes for stacking process	Optimal routing straddle carriers throughout the stack
	Identification of optimal stacking strategy		Establishing sequence in which containers are retrieved from the stack
	Identification of optimal stack configuration		
Transporting containers to other transport modes	Selection of appropriate transport systems		

Appendix C

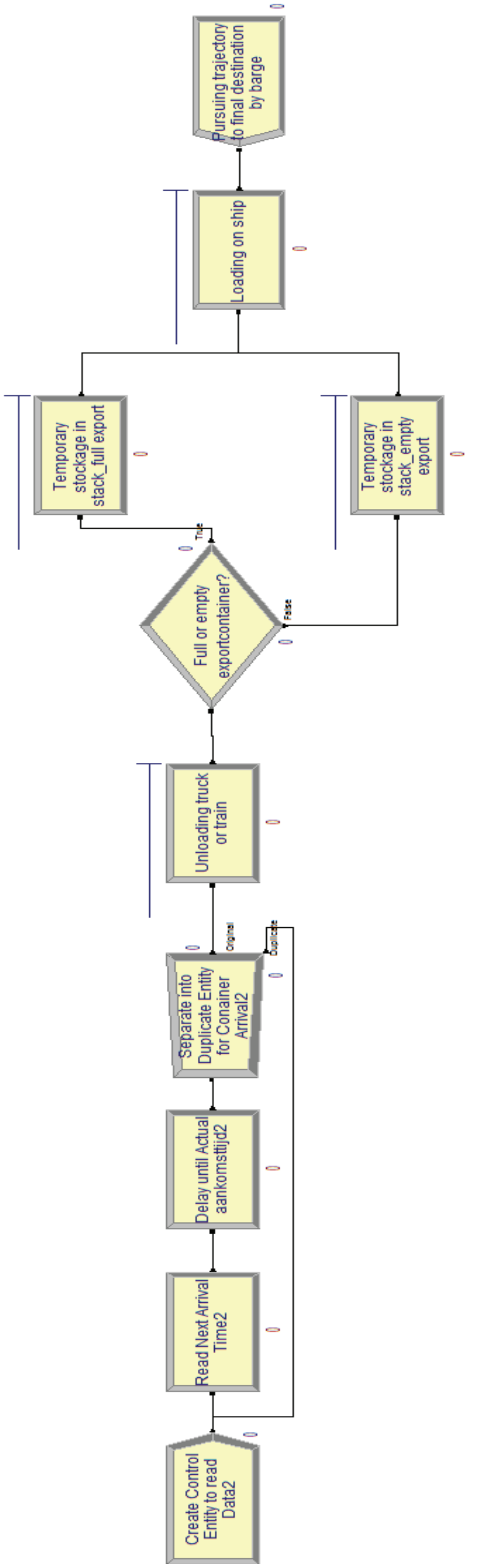

Figure 1: Import Container Transhipment in Arena

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COLLISION AVOIDANCE METHOD FOR MULTI-CAR ELEVATOR SYSTEMS WITH MORE THAN TWO CARS IN EACH SHAFT

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ABSTRACT
In multi-car elevator systems, several cars are installed in each elevator shaft to improve the transportation capability without increasing the occupied floor space. In our previous studies, we proposed an optimization-based method to avoid collisions between cars in the same shaft of multi-car elevator systems. However, it was applicable only to the systems with two cars in each shaft. In this study we will improve this method so that it can handle more than two cars. Then, its effectiveness will be examined by computer simulation.

Keywords: multi-car elevator system, collision avoidance, optimization-based method, computer simulation

1. INTRODUCTION
A multi-car elevator system is such an elevator system that several cars are installed in every elevator shaft. This type of elevator system has been attracting much attention (ThyssenKrupp Elevator 2005, Miyamoto and Yamaguchi 2008, Onat et al. 2011, Valdivielso and Miyamoto 2011) because it enables us to improve the vertical transportation capability with less floor space compared to the ordinary elevator systems. However, intelligent car group control is crucial to take full advantage of multi-car elevator systems.

The roles of a group control system are (1) to allocate calls (passengers) to cars and (2) to control cars so that collisions never occur. Miyamoto and Yamaguchi (2008) constructed a simulator of a multi-car elevator system called MceSim for CST Solution Competition held in Japan. Based on this simulator, Valdivielso and Miyamoto (2011) proposed call allocation methods. Although MceSim has a function to avoid collisions, this simulator is based on a simplified model of a multi-car elevator system because their focus was rather on call allocation methods. For example, the car stop time at a floor is constant regardless of the number of passengers who board or leave the car, a car can change its speed only step-wise every one second, and so on. On the other hand, our previous studies considered a more realistic multi-car elevator system where the car stop time cannot be known in advance by the system, and the acceleration and the jerk of cars are simulated exactly. In Tanaka and Watanabe (2009, 2010), we proposed a collision avoidance algorithm for this realistic system that dynamically optimizes the floors to be visited next by cars. Then, in Tanaka and Miyoshi (2011), two types of passenger guidance methods, immediate guidance and nonimmediate guidance were compared by computer simulation. However, the collision avoidance algorithm in our previous studies was not applicable to a system with more than two cars in each shaft.

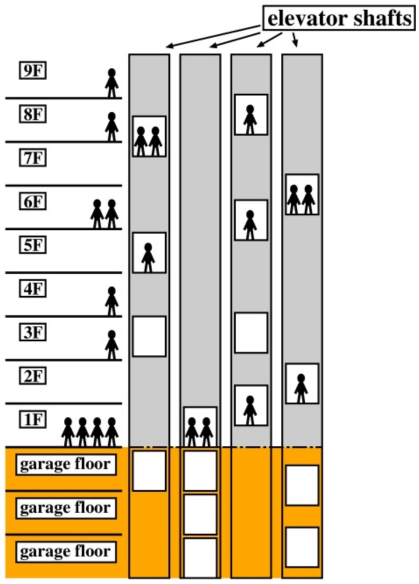
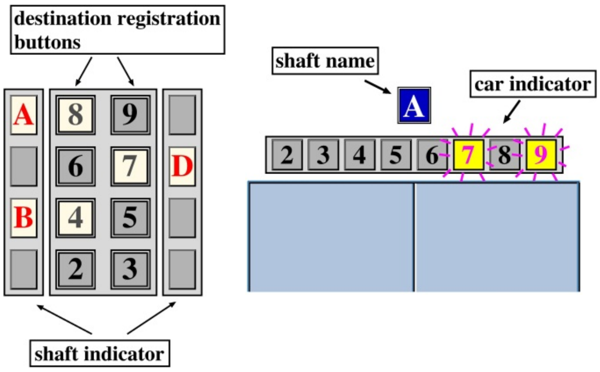


Figure 1: Multi-Car Elevator System

Our purpose in this study is to extend this algorithm so that it can handle more than two cars. Then, its effectiveness will be verified by computer simulation.

2. SYSTEM CONFIGURATION
Figure 1 gives a typical configuration of a multi-car elevator system. The first floor is the ground floor and there are garage floors underground so that the lower cars can escape to there when the upper cars are going to stop at the ground floor. On the other hand, there are no garage floors assumed on the top of the building. It follows that only the uppermost car in each shaft can stop at the highest floor. Therefore, the system should determine the assignment of cars to each passenger



(a) Destination registration buttons (b) Destination-based car guidance

Figure 2: Interface for Passengers

according to his/her destination floor. To achieve this, a destination-based call registration system is installed in multi-car elevator systems. A passenger who comes to an elevator hall calls a car by pushing the button of his/her destination floor (Fig. 2(a)) if it has not been pushed by another passenger. Then, the system immediately displays the shaft where he/she should wait for a car on the shaft guidance panel. In other words, we adopt the immediate passenger guidance policy. Finally, the car arrives at the floor and the car guidance panel displays the destination floors of passengers who should board that car (Fig. 2(b)).

The group control system for this multi-car elevator system is composed of a group controller and shaft controllers as shown in Fig. 3. When a new call is registered, the group controller immediately allocates it to some car and generates a travel schedule of that car by the selective-collective rule (Strakosch 1998), i.e. the ordinary elevator car operation, without considering collisions. This travel schedule is given by a visiting order of the origin and the destination floors of the calls allocated to that car. The travel schedules are passed to shaft controllers and they are modified so that collisions and reversal do not occur. Here, reversal is such an undesirable operation that a car travels in the direction opposite to the desired direction of on-board passengers. The shaft controllers should keep the visiting orders of the origin and destination floors in the travel schedules by the group controller, but it is possible that reversal cannot be avoided without modifying them. Hence, the visiting orders are modified only in such a case. It follows that the collision avoidance is performed mainly by inserting into the travel schedules, waits and/or evacuations to the floors where no passengers board nor leave the cars.

Since we do not assume that all the passengers push buttons to register their destination floors, the system cannot know how many passengers correspond to one call. It implies that the system cannot know the car stop time at a floor because how long it takes for a car to load or unload passengers at that floor cannot be known in advance. This setting is reasonable even when such a system is adopted that all the passengers

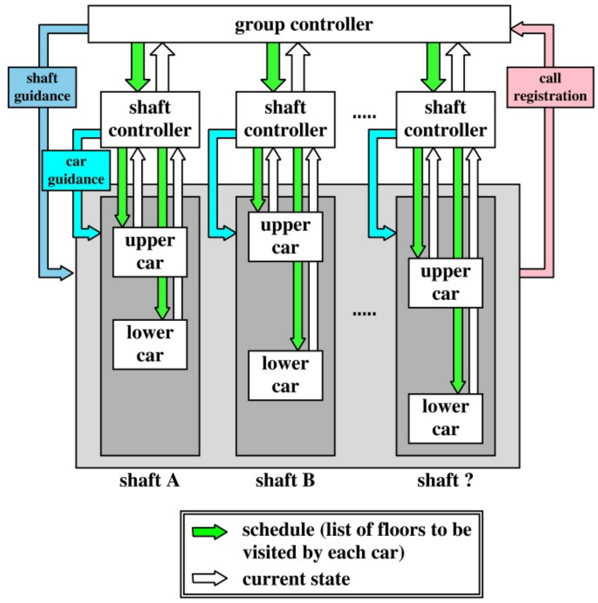


Figure 3: Group Control System for Multi-Car Elevator

push buttons and register their destination floors, because passenger boarding and leaving times vary in practice. Under this realistic setting, we are to consider a collision (and reversal) avoidance method.

3. OPTIMIZATION-BASED COLLISION AVOIDANCE

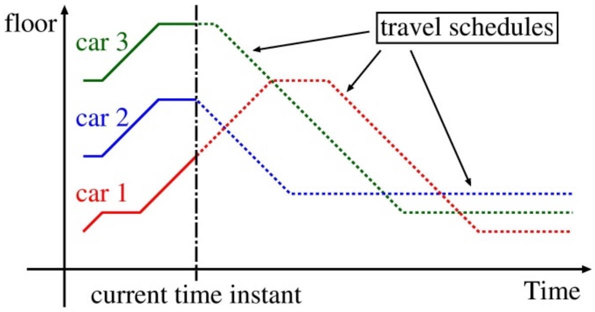
The framework of the collision avoidance method in this study is the same as that in our previous studies (Tanaka and Watanabe 2009, 2010). In this method, collisions are considered only until cars reach the floors to be visited next, and the cars are assumed to stay there infinitely long. The collision avoidance is considered again when one of the cars becomes ready to start. This is repeated until all the passengers are served.

The collision avoidance algorithm is triggered at the following instants:

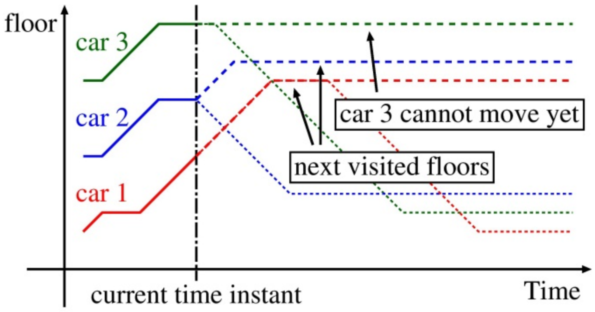
(a) A new call is allocated to one of the cars in the shaft.
(b) A moving car arrives and stops at a floor.
(c) A car finishes closing the door and becomes ready to start.

Figures 4(a) and 4(b) depict an example of our collision avoidance method. Since collisions occur in the travel schedules passed from the group controller, they are modified at the instant when the collision avoidance algorithm is triggered. At this instant, car 3 cannot move yet and hence is assumed to stay at the current floor infinitely long, while car 1 and car 2, which are already moving or can start moving, are assumed to stay at the next visited floors infinitely long.

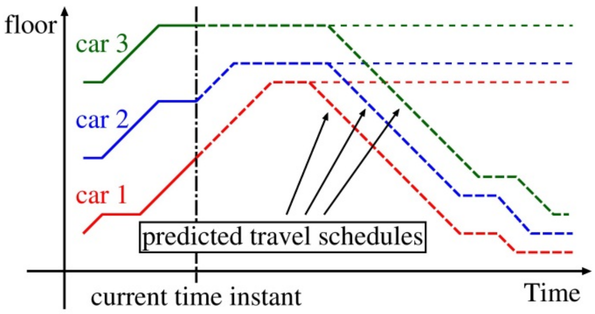
To achieve "good" collision avoidance, all the feasible combinations of the next visited floors such that collisions and reversal never occur are enumerated and the best combination that minimizes several types of objective functions is adopted. To evaluate one of the objective functions, future travel schedules after arriving at the next visited floors are necessary. To predict them as precisely as possible, the travel



(a) Time instant to determine the next visited floors



(b) Floors are determined to avoid collisions and reversal



(c) Prediction of the travels after the next visited floors

Figure 4: Concept of Dynamic Optimization for Collision Avoidance

schedules given by the group controller are modified by a collision avoidance rule and the obtained schedules are used (Fig. 4(c)). The primary reason why the method in our previous studies was not applicable to a system with more than two cars in each shaft is that this rule can consider only two cars. Therefore, in the next section, we will propose a new collision avoidance rule for the travel schedule prediction that is applicable to any number of cars.

4. COLLISION AVOIDANCE RULE FOR PREDICTION OF FUTURE CAR TRAVEL

The collision avoidance rule in our previous studies determines which car should wait and/or be evacuated based on the detailed model of car motion, i.e. by taking into account the acceleration and the jerk of a car. However, it is difficult to extend this to the case with more than two cars because the collision avoidance becomes much more complicated. Therefore, in this study, we propose a two-phase method as shown in Fig. 5. First, collision avoidance and reversal avoidance are

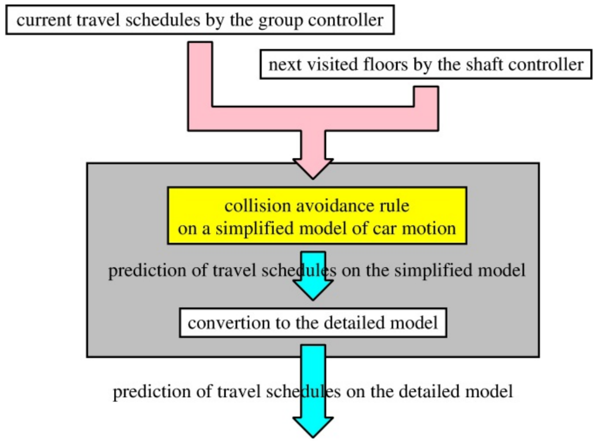


Figure 5: Prediction of Future Car Travel by a Collision Avoidance Rule

considered on a simplified model of car motion and then, the obtained travel schedules are converted by inserting appropriate waits so that collisions and reversal never occur on the detailed model. On the simplified model, the following assumptions are made:

(1) A car moves one floor in a unit time.
(2) A car can stop anytime.
(3) The floor stop time is zero.
(4) A collision occurs when more than one car occupies the same floor at a time.

Obviously, these assumptions make the collision avoidance much easier because the difference between the current position (floor) of a car and its previous position should be +1, 0 or -1 and hence we can move it step by step.

The outline of the collision avoidance rule for n_{C} cars (car 1, car 2, …, car n_{C} from the lowest to the highest) on the simplified model is as follows.

(0) Let the current time instant t be $t \coloneqq 0$ and denote the initial position of car i by s_{i0}. Let f_i^{turn} $(i = 0, \dots, n_{\mathrm{C}})$ be the floor where car i changes its direction for the first time in the travel schedule. If the travel schedule finishes without any direction change, let f_i^{turn} be the final floor in the travel schedule. If the travel schedule is empty, let $f_i^{\mathrm{turn}} \coloneqq \emptyset$. Let d_i denote the current destination of car i. If car i is not empty, it is initialized by the floor where it becomes empty for the first time in the travel schedule. Otherwise, $d_i \coloneqq \emptyset$.

(1) For each car i such that $d_i \neq f_i^{\mathrm{turn}}$, check if the car can reach f_i^{turn} without changing its direction. If there is more than one candidate, such a car is chosen first that interferes the less number of cars with $d_i \neq f_i^{\mathrm{turn}}$.

(2) Determine the next positions of cars at $t+1$, $s_{i,t+1}$, for the cars i with $d_i \neq \emptyset$ so that they approach their destinations d_i unless collisions nor reversal occur. In the case that a collision or reversal occurs between a pair of cars, the car nearest to its destination d_i is moved and the other car is kept waiting at the current position s_{it}.

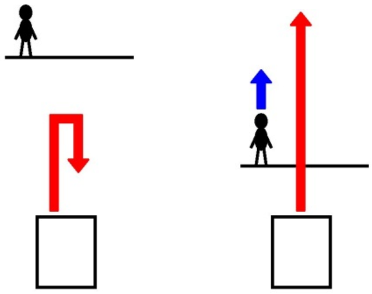


Figure 6: Unnatural Car Operations

(3) The next positions $s_{i,t+1}$ of cars i with $d_i = \emptyset$ are chosen from among $s_{it} - 1, s_{it}$ and $s_{it} + 1$ so that collisions never occur.
(4) Let $t := t + 1$. For the cars i with $s_{it} = d_i$, let $d_i := \emptyset$. Update f_i^{turn} if $s_{it} = f_i^{\mathrm{turn}}$.
(5) If $f_i^{\mathrm{turn}} = \emptyset$ for all i, terminate. Otherwise, go to (1).

Roughly speaking, this rule moves each car to the floor where it changes its direction next in the travel schedule while ensuring that collisions and reversal never occur. The following condition checks whether reversal becomes unavoidable between a pair of cars i and j ($i < j$):

$$s_{it} + j - i > d_j \wedge d_i + j - i > s_{jt}. \quad (1)$$

It is similar to the condition in Tanaka and Watanabe 2010 except the term $j - i$ to take into account the cars between the two cars.

The original travel schedules generated by the group controller are modified by the above rule so that collisions and reversal do not occur on the simplified model. The obtained travel schedule of a car is given by a visiting order of floors where some additional floors for evacuation are inserted into the original one. To convert such travel schedules into those on the detailed model, waits at the visited floors are inserted without changing the visiting orders of the floors so that collisions do not occur.

5. OBJECTIVE FUNCTIONS

As explained in Section 3, the next visited floors are evaluated by several types of objective functions in our collision avoidance method. These objective functions will be briefly introduced in this section.

In the proposed method, the following five types of objective functions are employed.

(1) The number of such cars that the visiting orders of the floors in the travel schedules are modified to avoid reversal. This objective function is to reduce unnecessary modifications of the visiting orders as much as possible (see Section 2).
(2) The number of empty cars that satisfy one of the following conditions.
   (a) It changes the direction although it is approaching the floor scheduled next in the travel schedule.
   (b) It skips the floor to be visited next in the travel schedule and its direction is the same as that of the passengers who are waiting for the car at that floor.

   This objective function is to suppress unnatural operations (see Fig. 6).
(3) Total service time of passengers. The service time of a passenger is the time from when he/she comes to the elevator hall of his/her origin floor until when he/she finishes leaving a car at his/her destination floor. Since the number of passengers that correspond to one call is unknown to the system, it is assumed to be one. This objective function is to achieve as good collision avoidance as possible.
(4) Total absolute difference between the next visited floor and the floor to be visited next in the travel schedule. This objective function is to follow the travel schedules by the group controller as much as possible.
(5) Total absolute difference between the current floor and the next visited floor for the cars without allocated calls. This objective function is to suppress unnecessary travels of empty cars.

These objective functions are evaluated in the lexicographical order. More specifically, if (1) is the same, (2) is evaluated and if (2) is the same, (3) is evaluated, and so on. Among them, (3) requires the future travel schedules after the next visited floors.

6. COMPUTER SIMULATION

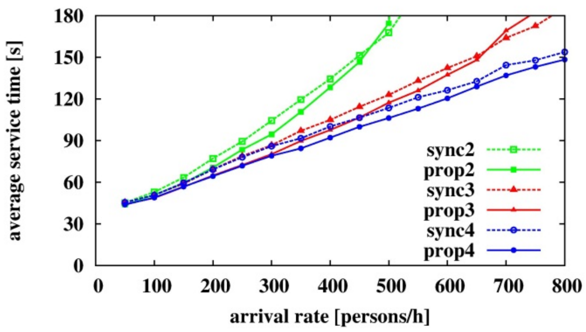
In this section the effectiveness of the proposed collision avoidance method will be examined by computer simulation. The specifications of the system follow Tanaka and Watanabe (2009, 2010), which are summarized in Table 1.

Table 1: System Specifications

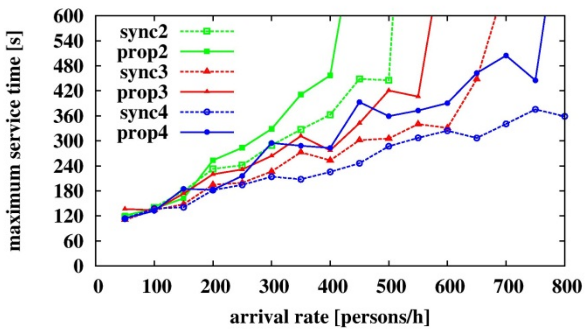
Number of floors	30
Interfloor distance	4.33m
Passenger boarding/leaving time	1.2s/person
Passenger response time	2.0s
Door opening time	1.8s
Door closing time	2.4s
Maximum speed	6m/s
Maximum acceleration	1.1m/s^2
Jerk	2.0m/s^3
Car capacity	20persons

Data sets of passengers are generated as follows. Passenger arrival times at elevator halls are generated from the uniform distribution [0, 7200) (in seconds). Their origin and destination floors are randomly generated to simulate two types of passenger traffic, uppeak traffic and downpeak traffic, and the ratios among

(1) the number of passengers from the 1st floor,
(2) the number of passengers to the 1st floor,
(3) the number of upward passengers that travel between floors other than the 1st floor,

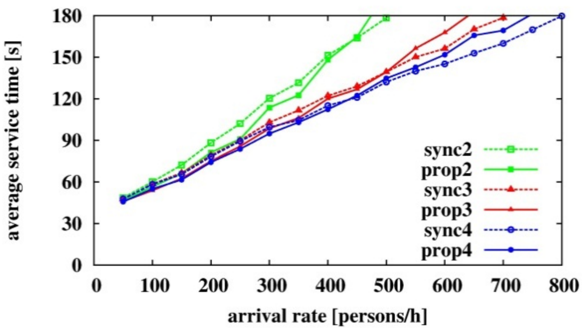


(a) Average service time

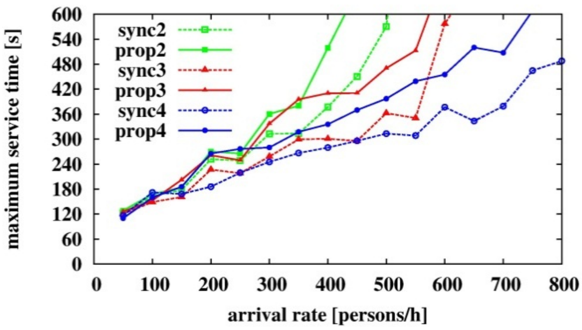


(b) Maximum service time

Figure 7: Results for Single-shaft System (Uppeak)



(a) Average service time



(b) Maximum service time

Figure 8: Results for Single-shaft System (Downpeak)

(4) the number of downward passengers that travel between floors other than the 1st floor,

are set to (1):(2):(3):(4)=30:1:1:1 and 1:30:1:1, respectively. For each setting of the passenger arrival rate (the number of passengers per one hour) and the type of passenger traffic, 10 data sets are generated. To examine stationary performance, the average and maximum service times of passengers whose arrival times are in the interval [1800, 5400) are evaluated.

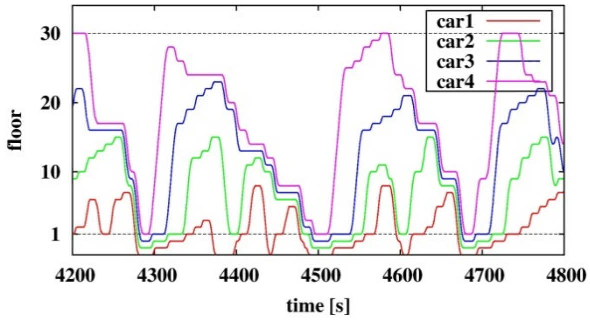
First, the simulation results for a system with a single shaft are shown. For comparison, we considered synchronous control (Valdivielso and Miyamoto 2011). This control restricts the directions of the cars in the same shaft so that they are always the same to make the collision avoidance easy. The allocation of a call to a car is determined by zoning (Strakosch 1998). It determines which car should serve a call by its origin floor (O_k) and destination floor (D_k) as follows. Let us denote the number of cars by n_C and number the cars from the lower to the upper as car 1, …, car n_C. Let us also denote the highest floor of the building by the M-th floor. If the direction of the call k is up, i.e. $O_k < D_k$, the call is allocated to car $\lceil n_C D_k / M \rceil$, where $\lceil a \rceil$ denotes the smallest integer that is not smaller than a. On the other hand, if the direction of the call is down, the call is allocated to car $\lceil n_C O_k / M \rceil$. In other words, the floors are equally divided into zones and each car serves only calls in its zone.

The results are summarized in Figs. 7 and 8. In these figures, the average or the maximum service time over 10 instances is depicted against the passenger arrival rate. In addition, "prop" and "sync" denote the results of the proposed method and the synchronous control, respectively, and the numbers at the tail of "prop" and "sync" denote the numbers of cars. From these figures, we can verify that the proposed method can improve the average service time compared to the synchronous control. However, the maximum service time is worse for both the types of traffic.

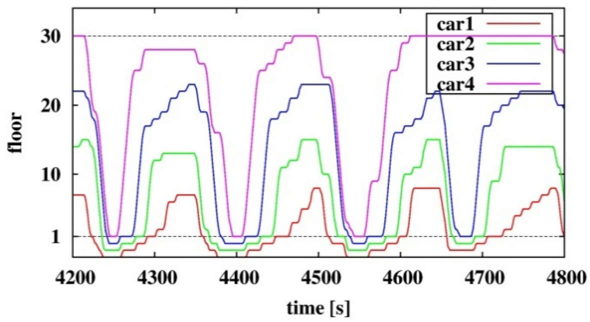
Figures 9(a) and 9(b) are examples of the obtained car diagrams by the proposed method and the synchronous control, respectively. From these figures, we can observe the reason why the maximum service time diverges for a smaller passenger arrival rate when the proposed method is applied. It is because the round trip time, i.e. the cycle of returning to the 1st floor becomes larger for upper cars compared to the synchronous control. Due to this larger round trip time, the number of passengers waiting for an upper car at the 1st floor reaches the car capacity in uppeak traffic. In this case, the car becomes full at the 1st floor and cannot serve other calls after that until at least one passenger leaves the car. Therefore, upward calls with lower origin floors are likely to be delayed and the maximum service time diverges. For downpeak traffic, a similar argument holds.

Next, computer simulation for a system with five shafts is performed. Since there is more than one shaft, we should allocate each call to some shaft, while car allocation in the shaft is determined by zoning. The shaft allocation is determined by the following simple algorithm (Tanaka and Watanabe 2009, 2010).

(1) For each shaft 1, 2, …, 5:



(a) Proposed method



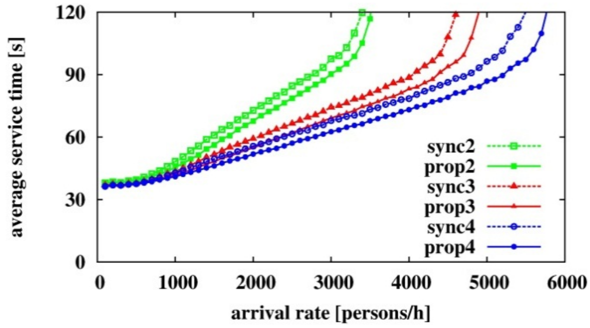
(b) Synchronous control

Figure 9: Examples of Car Diagrams (Four Cars, Uppeak)

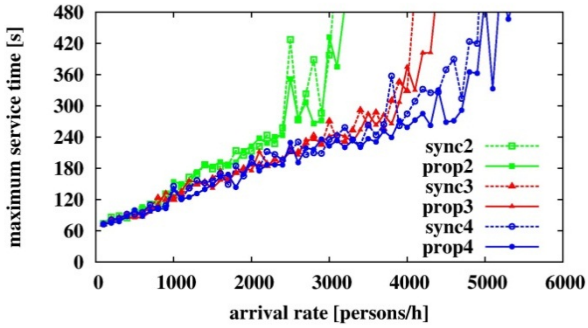
(i) Apply the collision avoidance rule in Section 4 to the current travel schedules of the cars in the shaft and compute the total service time in the shaft.
(ii) Allocate the call to the car in the shaft by zoning, and obtain the travel schedule by the selective-collective rule.
(iii) Apply the collision avoidance rule to the new travel schedules and compute the total service time.
(iv) Compute the increase of the total service time from (i) to (iii).

(2) Choose the shaft with the least increase of the total service time.

The results are shown in Figs. 10 and 11. The improvement from the synchronous control is more apparent in this case. This implies that the proposed method performs very well when the number of shafts increases and several cars in different shafts share one zone. To see this, the performance of the two methods is compared with the number of shafts changed. The results for $n_C = 4$ and downpeak traffic are shown in Fig. 12. In these figures, the horizontal axes are normalized by the number of shafts. Therefore, the unit is given by persons/h/shaft. In addition, the numbers before "sync" and "prop" denote the numbers of shafts. From this figure, we can see that the transportation capability per one shaft improves as the number of shafts increases and the improvement is larger for the proposed method than for the synchronized control. This would be because cars in different shafts are more likely to play different roles in the proposed method than those in the synchronous control that restricts the direction in each shaft and hence has less freedom of operation. This advantage is thought to contribute to the improvement of the transportation capability.

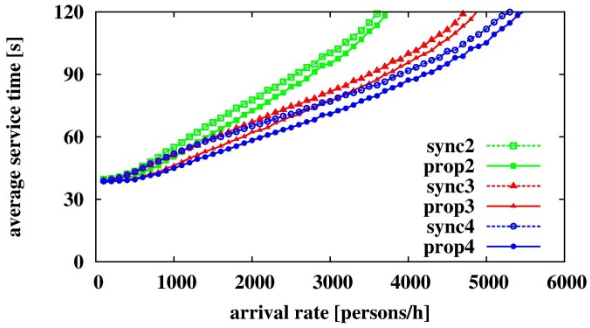


(a) Average service time

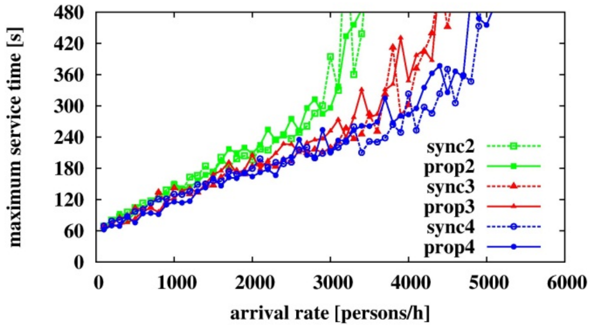


(b) Maximum service time

Figure 10: Results for Five-shaft System (Uppeak)



(a) Average service time

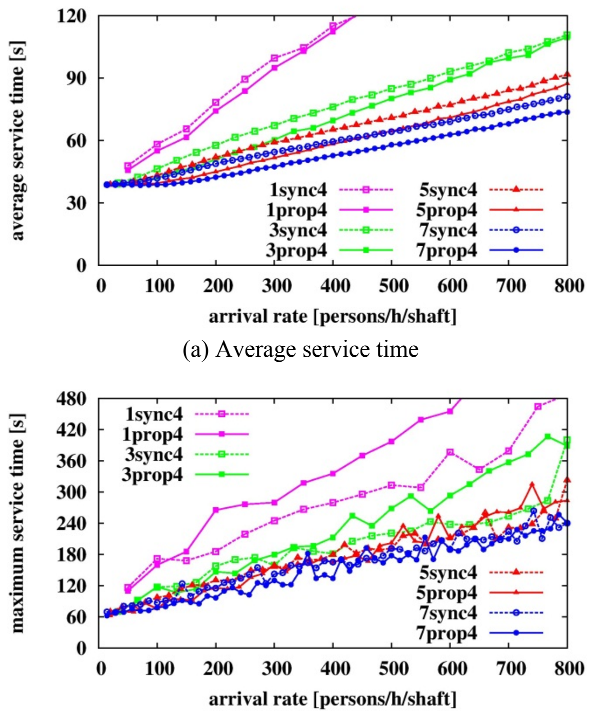


(b) Maximum service time

Figure 11: Results for Five-shaft System (Downpeak)

7. CONCLUSION

In this study we extended the previous collision avoidance method for multi-car elevator systems so that



(a) Average service time

(b) Maximum service time

Figure 12: Results When the Number of Shafts Are Changed (Number of Cars $n_C = 4$, Downpeak)

it becomes applicable to the systems with more than two cars in each shaft. Then, computer simulation was conducted to examine the effectiveness of the proposed method through the comparison with the synchronous control. As a result, it was verified that the proposed method can improve the transportation capability especially when the number of shafts is more than one, compared to the synchronous control. However, the maximum service time tends to increase because the proposed method does not try to minimize it. To improve the method for suppressing the maximum service time is left for future research. It would also be necessary to investigate more intelligent car allocation algorithms.

ACKNOWLEDGMENTS

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TIME-DEPENDENT ROUTING OF DRAYAGE OPERATIONS IN THE SERVICE AREA OF INTERMODAL TERMINALS

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ABSTRACT
In this paper the operational planning of drayage operations in the service area of intermodal terminals is studied. Drayage operations are the full truckload and empty container transport activities between container terminals, container depots, consignees and shippers. Most existing models consider travel times to be constant over time. In reality travel times depend on the time of the day. In this paper, time-dependent travel times are considered while planning daily drayage operations. A deterministic annealing meta-heuristic is proposed to solve the problem. The algorithm provides high quality results. Finally, two approaches to reduce computation time are presented.

Keywords: intermodal terminals, drayage operations, time-dependent travel times, vehicle routing

1. INTRODUCTION

Drayage operations refer to the full truckload container transport activities that take place on a regional scale around the intermodal container terminals. They involve the transport of loaded and empty containers between these container terminals, container depots, consignees and shippers. Drayage operations are mostly performed by truck and constitute a large part of total costs of an intermodal transport. Therefore, efficient planning of these operations is an important task. Special attention should be paid to minimizing empty container movements since these are costly activities which do not generate any revenue.

Often a sequential planning approach is proposed to plan daily drayage operations. First, an empty container allocation model is used to determine the optimal distribution of empty containers in the region, based on supply and demand information of consignees and shippers respectively. Next, a vehicle routing problem is solved to create efficient vehicle routes performing loaded and empty container transports. Recently, efforts to integrate both planning steps are introduced by several authors (Smilowitz 2006; Ileri 2006; Zhang, Yun, and Moon 2009; Zhang, Yun, and Kopfer 2010; Braekers, Caris, and Janssens 2012). In an integrated planning approach empty container allocation decisions are not taken in advance. Instead, these decisions are taken simultaneously with vehicle routing decisions. As a result, drayage costs may be reduced (Braekers, Caris, and Janssens 2012). Therefore, in this paper an integrated planning approach is used.

The majority of papers on the operational planning of drayage operations, like the ones mentioned above, make the simplifying assumption that travel times between locations are constant and only depend on the distance to be travelled. This is a very common assumption in vehicle routing literature. However, in reality travel times are not solely a function of the distance. Rather they will vary from time to time. Several causes of these variations in travel times may be identified. A major cause is the temporal variation in traffic density. Average traffic volumes are affected by hourly, daily, weekly and seasonal influences. Traffic density will be higher during peak hours than during non-peak hours while holidays and specific events may result in daily or weekly variations. Other causes of travel time variation include stochastic or unforeseeable events like accidents, vehicle breakdowns and weather conditions. (Malandraki and Daskin 1992; Balseiro, Loiseau, and Ramonet 2011) Neglecting the time-dependency of travel times may seriously affect the applicability of vehicle routing models in practice, especially when time windows at customers are involved and vehicle movements are planned in heavily congested areas (Hill and Benton 1992).

In this paper, the effect of hourly variations in travel times on the operational planning of drayage operations is studied. Travel times are assumed to be a deterministic function of the distance and the time of the day. This means that although travel times are not constant during the planning period, travel times at each point in time are known in advance. As a result, a deterministic planning approach may be used. Travel time variations due to random events like weather conditions and accidents are not considered. To take these variations into account, a stochastic approach should be considered.

Related literature is reviewed in Section 2. In Section 3, a detailed problem description is presented. A time-dependent version of the deterministic annealing algorithm for the integrated drayage problem presented in Braekers, Caris, and Janssens (2012) is introduced in Section 4. Results on randomly generated problem instances are discussed in Section 5. Finally, Section 6 contains conclusions and opportunities for further research.

2. LITERATURE REVIEW

In this section, an overview of literature on time-dependent vehicle routing is presented. For a detailed review of literature on drayage operations, the reader is referred to Braekers, Caris, and Janssens (2012).

Vehicle routing with time-dependent travel times is a relatively new research direction. The first steps to account for time-dependency of travel times in vehicle routing problems are presented by Hill and Benton (1992) and Malandraki and Daskin (1992). Hill and Benton (1992) propose to calculate time-dependent travel times on a link by using the average of speed levels in the area of the origin and destination. Malandraki and Daskin (1992) propose to use stepwise functions for modelling travel time variations. The planning period is divided in a number of intervals and the travel time on a link differs from interval to interval. As a result, the travel time on a link makes a jump at discrete moments in time. A major drawback of these early approaches is that they violate the non-passing or FIFO ('First-In-First-Out) property. This property encompasses the common sense idea that when a vehicle leaves node i for node j at a given time, any identical vehicle that leaves node i at a later time, cannot arrive earlier at node j. (Ahn and Shin 1991, Malandraki and Dial 1996).

Fleischmann, Gietz, and Gnutzmann (2004) describe a method to exclude the possibility of passing. The authors propose to remove the discrete jumps in stepwise travel time functions by smoothing the function. This smoothing relies on two parameters that have to be set appropriately. The resulting smoothed travel time function satisfies the non-passing property as long as the slope of the function is larger than minus one at any point (Fleischmann, Gietz, and Gnutzmann 2004; Kuo, Wang, and Chuang 2009). Another method to ensure the non-passing property is presented by Ichoua, Gendreau, and Potvin (2003). The authors propose to use a stepwise function for travel speed instead of a stepwise function for travel time. This means that the speed on a link changes at discrete points in time. It is easy to see that this method satisfies the non-passing property since at any time all vehicles travelling along an arc will have the same speed no matter where they are.

Recently, time-dependency of travel times in vehicle routing problem has received increased research attention. All recent papers consider travel times that satisfy the non-passing property.

To the authors' knowledge, only Namboothiri and Erera (2004) deal with time-dependent travel times in drayage operations. The authors study a drayage problem involving the transport of loaded containers between customers and a single terminal at the port. Delays at the terminal due to congestion are the only source of time-dependency of travel times. Exact and heuristic column generation approaches are proposed to solve the problem.

Other research on time-dependent vehicle routing has mainly focused on the Time-Dependent Vehicle Routing Problem (TD-VRP) and its variant where time windows at customers are imposed (TD-VRPTW). Exact approaches for the TD-VRPTW are proposed by Soler, Albiach, and Martinez (2009) and Dabia, Ropke, and Van Woensel (2011). Soler, Albiach, and Martinez (2009) describe a method to transform the problem to an asymmetric capacitated vehicle routing problem which may be solved exactly for small problem instances. Dabia, Ropke, and Van Woensel (2011) present a column generation approach embedded in a branch and cut framework. Due to the complexity of the problems, most research has focused on the development of (meta)-heuristics. Kuo, Wang, and Chuang (2009) and Jabali et al. (2009) propose tabu search algorithms for the TD-VRP. Jung and Haghani (2001) and Haghani and Jung (2005) present a genetic algorithm on the dynamic time-dependent vehicle routing problem with mixed linehauls and backhauls. Hashimoto, Yagiura, and Ibaraki (2008) discuss an iterated local search algorithm for the TD-VRPTW. Ant colony system algorithms for this problem are proposed by Donati et al. (2008) and Balseiro, Loiseau, and Ramonet (2011). Figliozzi (2012) proposes a solution algorithm based on a route construction and route improvement heuristic while Kok, Hans, and Schutten (2011) study a TD-VRPTW where driving regulations are imposed. Finally, vehicle routing problems with stochastic time-dependent travel times are studied by Van Woensel et al. (2007, 2008) and Lecluyse, Van Woensel and Peremans (2009).

3. PROBLEM DESCRIPTION

The problem studied in this paper is to construct efficient vehicle routes performing all loaded and empty container transports during a single day in the service area of one or more intermodal container terminals. Only full truckload container transports are considered.

A loaded container transport represents a full truckload transport from a shipper to a container terminal (outbound loaded container) or from a container terminal to a consignee (inbound loaded container). For each container, the terminal to be used is predefined so that for all loaded container transports the origin and destination are known in advance. Time windows are imposed on these transport tasks.

For empty container transports, either the origin or the destination is not defined in advance. A shipper may request an empty container to be delivered before a specific point in time. The origin of this empty container is irrelevant for the shipper and can be chosen by the decision maker. On the other hand, a consignee will have an empty container available after unloading an inbound loaded container. This container becomes available at a certain point in time and should be picked up before the end of the day. The destination of the empty container is determined by the decision maker. Empty containers can thus be transported from consignees to container terminals, from container terminals to shippers or directly from consignees to shippers.

A homogeneous fleet of vehicles with a single container capacity is assumed. All vehicles start and end their route at the vehicle depot. When a vehicle arrives early at a location, waiting is allowed at no cost. The service time to pickup and drop off containers is constant and the same for loaded and unloaded containers. A hierarchical objective function is used. The primary objective is to minimize the number of vehicles used while the secondary objective is to minimize total route duration (sum of travel, service and waiting times).

An example of a small problem is shown in Figure 1a. The problem consists of a single vehicle depot, two container terminals, an inbound loaded container transport task, an outbound loaded container transport task, an empty container supply location and an empty container demand location. When no time windows are imposed, Figure 1b shows the optimal solution for this problem. A single vehicle is used to execute all transportation tasks. First, the vehicle performs the inbound loaded container transport task. Second, an empty container is transported directly from the empty container supply location to the empty container demand location. Finally, the vehicle performs the outbound loaded container transport task before returning to the vehicle depot.

Time-dependent travel times are calculated using the method of Ichoua, Gendreau, and Potvin (2003). The eight hour planning period is divided in five intervals. For each link in the network, a speed distribution over all five intervals is defined. In literature, often different speed levels are assigned to different (types of) links in the network. In our opinion this requires a good understanding of the different types of links and the extent to which they are subject to congestion. This may be the case when working with travel speeds on an actual road network. On the other hand, (randomly) assigning speed distributions to links might not make much sense when working with problem instances which are randomly generated on a Euclidean plane like here. Therefore, in this work the assumption is made that the whole region in which drayage operations take place is equally affected by congestion during peak hours. This means that all links in the network have the same speed distribution. A similar approach is considered by Jabali et al. (2009) and Figliozzi (2012). Speed during the first, third and fifth interval is assumed to be 60 kilometres per hour while speed drops to 36 kilometres per hour due to congestion during periods two and four. An overview of the speed distribution and the corresponding travel times on a link of 20 kilometres is shown in Figures 2 and 3.

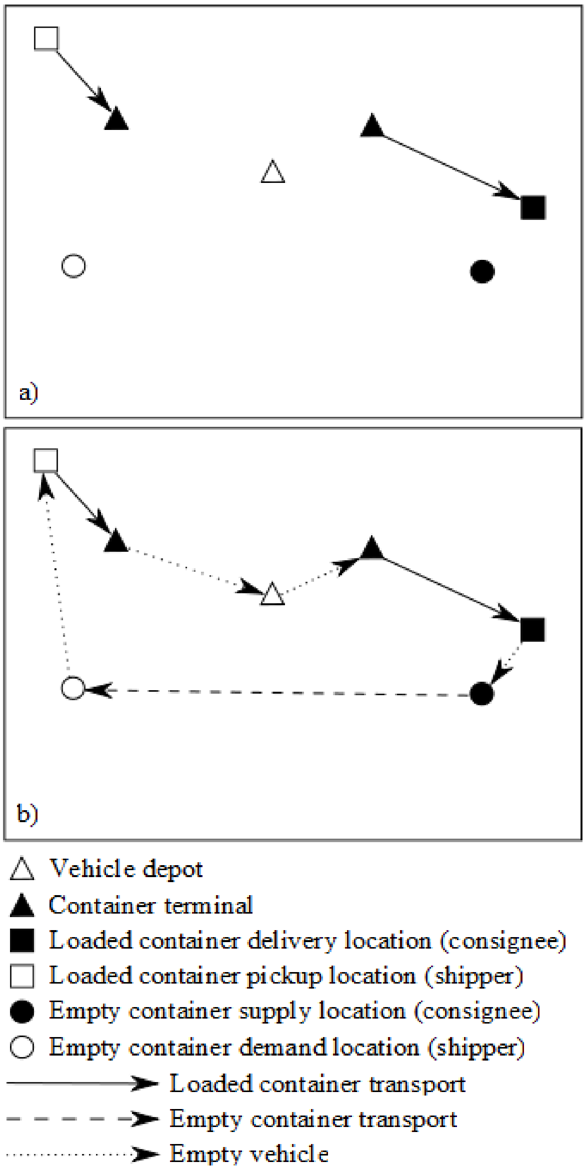

Figure 1: Small Problem Example with Solution

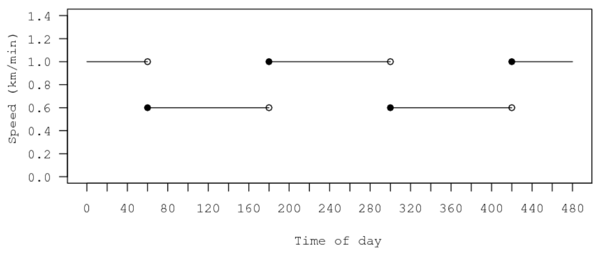

Figure 2: Speed Distribution

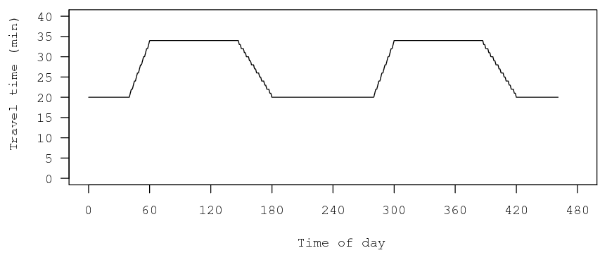

Figure 3: Travel Times on a Link of 20 Kilometres

4. PROBLEM FORMULATION

The problem described in the previous section may be formulated as an asymmetric multiple vehicle Travelling Salesman Problem with Time Windows (am-TSPTW) as is shown in Zhang, Yun, and Moon (2009) and Braekers, Caris, and, Janssens (2012). The problem is defined on a graph $G = (N, A)$ with node set N and arc set A. The node set $N = \{0,1, \dots, n\}$ consists of a vehicle depot (N_{VD}, index 0), a set of nodes for the loaded container transport tasks (N_L), a set of nodes for the empty container demand locations (N_D) and a set of nodes for the empty container supply locations (N_S). Each node has a time window $[a_i, b_i]$ during which it should be visited. The vehicle depot (as well as the container terminals) are opened during the whole planning period $[0, P]$.

When travelling between certain types of nodes, an intermediate stop at a container terminal is required. This is the case when travelling:

- from an empty container supply node to the vehicle depot, a loaded container task or another supply node,
- from the vehicle depot, a loaded container task or an empty container demand node to another container demand node.

In the first case, it is necessary to drop off the empty container which was picked up at the supply node before the vehicle is able to finish its route at the vehicle depot, transport a loaded container or pickup another empty container. The terminal which is used to drop off the empty container is chosen such that the duration of the detour is as small as possible. Similarly, when leaving the vehicle depot, finishing a loaded container task or dropping of an empty container at a demand node, an empty container needs to be picked up at a container terminal before travelling to an empty container demand node.

The arrival time function $A_{ij}(t)$ indicates the earliest arrival time at node j when a vehicle leaves node i at time t. The time needed to arrive at node j when leaving node i at time t is equal to $A_{ij}(t) - t$ and includes the execution of the loaded transport task at node i (if $i \in N_L$), the time to travel from node i to node j including a possible detour to a container terminal, container pickup and drop off times and possible waiting times at node j.

Travel times between two locations are calculated using the method of Ichoua, Gendreau, and Potvin (2003) which ensures that the non-passing property is satisfied. As a consequence, the arrival time function is a monotonic increasing function. Hence the inverse of the function $A_{ij}^{-1}(t)$ exists as well. This inverse function indicates the latest arrival time at node i in order to arrive at node j at the latest at time t. The values of $A_{ij}^{-1}(t)$ are calculated in a similar way as those of $A_{ij}(t)$. The major advantage of the existence of the inverse function is that it is possible to calculate backwards in a route. Hence, route feasibility checks may be formed in constant time (Ahn and Shin 1991; Fleischmann, Gietz, and Gnutzmann 2004; Donati et al 2008).

The arc set in the network is composed of all links (i, j) which are feasible: $A = \{i, j \in N, i \neq j, A_{ij}(a_i) \leq b_j\}$. The set of vehicles is indicated by K (index k) while M represents a very large number. Two types of variables are considered: binary variables x_{ij}^k which indicate whether a vehicle k travels directly from node i to node j, and variables t_i^k which indicate the arrival time of vehicle k at node i. The problem is formulated as follows:

$$\text{lexmin} \begin{pmatrix} \sum_{k \in K} \sum_{i \in N} x_{0i}^k , \\ \sum_{k \in K} \left(\sum_{i \in N} x_{i0}^k A_{i0}(t_i^k) - t_0^k \right) \end{pmatrix} \quad (1)$$

Subject to:

$$\sum_{k \in K} \sum_{j \in N} x_{ij}^k = 1 \qquad \forall i \in N \backslash \{0\} \quad (2)$$

$$\sum_{k \in K} \sum_{j \in N} x_{0j}^k \leq |K| \quad (3)$$

$$\sum_{j \in N} x_{ij}^k = \sum_{j \in N} x_{ji}^k \qquad \forall i \in N, \forall k \in K \quad (4)$$

$$A_{ij}(t_i^k) \leq t_j^k + (1 - x_{ij}^k) M \qquad \forall (i, j) \in A, j \neq 0 \quad \forall k \in K \quad (5)$$

$$A_{i0}(t_i^k) \leq P + (1 - x_{i0}^k) M \qquad \forall i \in N, \forall k \in K \quad (6)$$

$$a_i \leq t_i^k \leq b_i \qquad \forall i \in N, \forall k \in K \quad (7)$$

$$t_i^k \geq 0 \qquad \forall i \in N, \forall k \in K \quad (8)$$

$$x_{ij}^k \in \{0,1\} \qquad \forall (i, j) \in A, \forall k \in K \quad (9)$$

A hierarchical or lexicographic objective function is used (1). The primary objective is to minimize the number of vehicles used while the secondary objective is to minimize total route duration. Constraints (2), (3) and (4) are flow constraints. Constraint (5) ensures that a vehicle cannot arrive at a node before leaving the previous node and travelling to the new one. Constraint (6) ensures that all vehicles return to the vehicle depot before the end of the planning period. Time windows are represented by constraint (7). Finally, constraints (8) and (9) determine the domains of the decision variables.

5. TIME-DEPENDENT ALGORITHM

In this section, a two-phase deterministic annealing algorithm is presented for the integrated time-dependent drayage problem. Only a brief discussion of the general structure of this algorithm is presented here since it is similar to the algorithm discussed in Braekers, Caris, and Janssens (2012) for the time-independent integrated problem.

The algorithm starts with an initial solution which is constructed using a simple parallel insertion heuristic.

In the first phase of the algorithm, the number of vehicles is minimized while partially ignoring the secondary objective of minimizing total route duration. During the second phase of the algorithm, total route duration is minimized while the number of vehicles is kept fixed at its minimal value obtained in phase one.

During both phases, a deterministic annealing meta-heuristic is implemented to guide the search. Deterministic annealing is a meta-heuristic based on local search. During each iteration, neighbours of the current solution are found by local search operators. A neighbour is accepted to become the new current solution when it is better than the current solution or when the worsening in the objective value is smaller than a deterministic threshold value T. This deterministic threshold value is gradually lowered during the search. (Dueck and Scheuer 1990)

Details on the implementation of the local search operators and the calculation of the optimal departure time of vehicles at the depot are presented in the following paragraphs. Two approaches to reduce computation times of the algorithm are discussed as well.

5.1. Optimal Departure Time

In the time-independent case, the departure time of a vehicle which minimizes the duration of a route is equal to the latest possible departure time. By leaving the depot as late as possible, waiting times at customers are avoided as much as possible. Unfortunately, this is no longer true when travel times are time-dependent. Leaving the depot earlier than the latest possible time, might result in a route of shorter duration.

In this paper, the optimal departure time of a vehicle at the depot t_0^k is determined as follows. First, an interval in which t_0^k lies is determined. The upper bound of this interval is the latest departure time which satisfies time window constraints. The lower bound is equal to the departure time which corresponds with the earliest possible return time at the depot. This value can be found by a single backward loop through the route. Leaving the depot earlier than this value would result in waiting times along the route and hence in longer route durations. Second, for each departure time in the interval, the corresponding route duration is calculated by a forward loop through the route. Finally, the departure time which results in the smallest tour duration is selected.

5.2. Local Search Operators

Six different local search operators are implemented (Braekers, Caris, and Janssens 2012). Feasibility of local search moves may be checked in constant time, like in the time-independent case (see Section 4). However, evaluating the effect of a local search move on total route duration is much more complex when travel times are time-dependent. A shift in the arrival time at a node does not only affect arrival and waiting times at other nodes in the route. It may affect the travel time between any pair of consecutive nodes in the route as well. As a result, it is not possible to predict the effect of a local search move on total route duration (Fleischmann, Gietz, and Gnutzmann 2004).

The local search operators which only affect the total duration of a solution (*intra-route, relocate, 2-Opt*, exchange*) are implemented as follows. Each time a feasible local search move is found, the move is carried out, optimal departure times of the vehicle are recalculated and the effect on route duration is found. When this effect is acceptable (lower than the threshold), the neighbouring solution is accepted. Otherwise the local search move is reversed and the search of the operator is continued.

The two operators that reduce the number of routes are implemented in a different way. These operators are involved with re-inserting multiple nodes during a single local search move. Often multiple feasible insertion positions for each node can be found. Evaluating the effect on total route duration for all feasible positions would take too much computation time. Therefore, the effect on total route duration is estimated by looking at the effect on total minimal duration, where total minimal duration is defined as the sum of the smallest possible travel times on each link in the solution. This effect can be calculated in constant time. Selecting the insertion positions in this way offers the advantage that the optimal departure times of the vehicles at the depot and the corresponding total route duration do not have to be updated after every insertion. Instead they are updated when all nodes are inserted and only when the operator succeeds in reducing the number of vehicles.

5.3. Speed-up Approaches

To reduce the computation time of the algorithm, two speed-up approaches are considered. These approaches are compared with the base algorithm (v0) in the Section 6.

The first approach (v1) is to calculate the optimal departure time of a vehicle only in a post-optimization phase, rather than recalculating it every time a local search move changes the route. Dabia, Ropke, and Van Woensel (2011) note that this is a common approach, both in literature and practice. During the search, the latest possible departure time at the depot is assumed to be the optimal one. To reduce the risk of ignoring potentially promising solutions, the fifty best solutions are stored during the search instead of just the single best solution. In a post-optimization phase, the optimal departure times are calculated for each of these fifty solutions and the solution which offers the lowest total route duration is reported.

The second speed-up approach (v2) is related to reducing the number of feasible local search moves which are carried out and subsequently need to be reversed. This occurs when the increase in total route duration is larger than the deterministic threshold value T. It is proposed to only carry out a selection of the feasible local search moves while rejecting other moves immediately. This selection is based on the effect of a local search move on total minimal duration. Moves which result in an increase in total minimal duration which is larger than the current threshold values T plus its maximum value T_{max}, are rejected immediately. The idea is that a move which results in a considerable increase in total minimal duration will probably not result in an acceptable effect on total route duration. Finally, a combination of both speed-up approaches (v3) is considered.

6. EXPERIMENTAL RESULTS

The proposed deterministic annealing algorithm is tested on a set of randomly generated problem instances. A 2^4 full factorial design is set up to ensure the robustness of the algorithm. For each of the 16 problem classes, 3 random problem instances are generated. Lower bounds on the number of vehicles and on total route duration are found by a time window partitioning method. For a detailed description of the factorial design and the calculation of the lower bounds, the reader is referred to Braekers, Caris, and Janssens (2012).

Table 1 gives an overview of the average results over fifty runs of the algorithm. Detailed results for the base algorithm (v0) are available in appendix. It is clear that the algorithm provides high quality results. Using one of the speed-up approaches (v1, v2), hardly affects solution quality while computation times are reduced by 20 to 25%. Even when a combination of both speed-up approaches is considered (v3), the negative effect on solution quality is limited while computation times are reduced by 30%.

Table 1: Overview of Results

Values	Average results			
	v0	v1	v2	v3
Vehicles used	11.16	11.17	11.17	11.17
Gap (absolute)	1.16	1.17	1.17	1.17
Duration	4751	4752	4751	4752
Gap (%)	3.40	3.41	3.40	3.43
Comp. time (s)	14.87	11.74	11.14	10.35

7. CONCLUSIONS

In this paper, it is studied how hourly variations in travel times due to congestion can be taken into account when planning drayage operations. An integrated planning approach is considered. The objective is to minimize first the number of vehicles and second total route duration. A deterministic annealing meta-heuristic is proposed to solve the problem. This algorithm provides high quality results. Finally, two approaches to speed-up the algorithm are proposed.

In the future, supplementary computational tests could be performed. It would be interesting to analyze the performance of the algorithm when not all links in the network have the same speed distribution. Furthermore, more complex speed distributions with multiple speed levels may be considered. Another interesting research direction would be to study a dynamic version of the problem where transportation tasks become known during the day and travel times are not necessarily known at the beginning of the planning period.

APPENDIX

Average results over fifty runs of the base algorithm (v0) are shown in Table A.1. The first two columns indicate the average number of vehicles used and the absolute gap with the lower bound. Columns three and four show the average total duration and the relative gap with the lower bound.

Table A1: Detailed Results

Instance	Results			
	V	ΔV	D	ΔD
1.1	7.00	0.00	2807	2.97
1.2	7.00	1.00	2921	1.46
1.3	7.00	1.00	2861	2.86
2.1	7.00	1.00	2871	1.44
2.2	6.00	0.00	2697	2.87
2.3	7.00	1.00	2739	2.21
3.1	6.00	0.00	2558	2.65
3.2	6.00	0.00	2626	2.69
3.3	7.00	1.00	2785	2.44
4.1	6.00	0.00	2534	2.14
4.2	6.00	1.00	2433	2.03
4.3	6.00	1.00	2416	1.78
5.1	12.66	1.66	5457	3.65
5.2	13.00	1.00	5548	2.35
5.3	13.00	1.00	5496	3.24
6.1	13.00	1.00	5602	4.30
6.2	12.00	1.00	5411	5.84
6.3	12.00	1.00	5407	4.98
7.1	11.04	0.04	4968	3.72
7.2	11.80	0.80	5076	2.47
7.3	11.44	0.44	5031	2.68
8.1	11.00	1.00	4830	4.64
8.2	11.00	1.00	4826	5.32
8.3	11.00	1.00	4780	5.85
9.1	10.00	1.00	4298	2.03
9.2	11.00	1.00	4642	0.98
9.3	10.00	0.00	4187	2.61
10.1	10.00	1.00	4281	1.70
10.2	9.00	1.00	3856	1.51
10.3	9.00	1.00	3869	2.70
11.1	9.00	1.00	3703	3.40
11.2	8.90	0.90	3527	2.68
11.3	9.00	1.00	3711	2.20
12.1	8.00	1.00	3413	3.14
12.2	8.00	1.00	3442	3.19
12.3	9.00	1.00	3699	2.21
13.1	19.00	3.00	7934	4.26
13.2	18.00	2.00	7733	2.93
13.3	18.80	2.80	7724	3.12

14.1	18.90	2.90	7932	5.65
14.2	18.00	2.00	7729	5.16
14.3	17.98	2.98	7526	5.46
15.1	15.64	1.64	6679	4.34
15.2	16.76	2.76	7016	4.06
15.3	15.94	1.94	6677	4.21
16.1	15.00	2.00	6453	6.65
16.2	15.00	1.00	6690	6.00
16.3	15.00	2.00	6639	6.23

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CONCEPTUAL PROCEDURE FOR GROUPING LOGISTICS OBJECTS FOR MESOSCOPIC MODELING AND SIMULATION

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ABSTRACT

The field of logistics is confronted with an increasing complexity. This mainly results from the immense amount of goods which are part of logistics systems and processes. To address that the description of logistics systems and processes is to be conducted from an object oriented point of view by including object characteristics and their relations among each other. Therefore, in context of mesoscopic modeling and simulation, this paper presents a procedure which supports the conceptual modeling phase of the mesoscopic simulation approach in grouping and aggregation of logistics objects, i.e. goods and products, in an effective and credible way. This is considered as a method of simplification and will contribute to better model credibility and simulation efficiency as well as reducing model complexity.

Keywords: grouping, aggregation, logistics objects, mesoscopic modeling and simulation, logistics systems, complexity

1. INTRODUCTION

The field of logistics is confronted with an increasing complexity. Due to globalization production and logistics networks are becoming more international and the number of involved parties is increasing (Simchi-Levi 2008, p. 312). A rising variant diversity of products, a growing amount of globally sourced goods as well as an increasing availability of information due to new identification technologies contribute to that. Besides rising customer demands, decreasing length of product life cycles or increasing costs pressure, the complexity and heterogeneity of networks mainly result from the immense amount of goods which are part of logistics systems and processes (Bretzke 2010, pp. 1–4; Schenk et al. 2006). This trend has an impact on the sensitivity to disturbances of logistics networks, as well. According to this, tools of modeling and simulation provide suitable methods to analyze logistics systems as well as to support a fast adaptation process to changes and disturbances.

Here, the mesoscopic modeling and simulation approach seems to be very promising due to its trade off between simulation time and accuracy as well as providing the opportunity of incorporating logical groups of objects.

To address the rising diversity among the goods, which is a driving factor for complexity, the description of logistics systems and processes is to be conducted from an object oriented point of view by including object characteristics and their relations among each other. This comprises the application of appropriate concepts for incorporating that aspect and for grouping objects as well as defining standard processes to provide efficient solutions.

In this paper we consider logistics objects to be “physical goods such as raw materials, preliminary products, unfinished and finished goods, packages, parcels and containers or waste and discarded goods. Also, animals and even people can be logistics objects, which need special care and service” (Gudehus and Kotzab 2009, p. 3). But besides these physical objects also information are to be considered as logistics objects, often referred to abstract objects (Arnold et al., p. 3; Schenk 2007).

The objective of this paper is to present a procedure which supports the conceptual modeling phase of the mesoscopic simulation approach in grouping logistics objects in an effective and credible way. This will contribute to better model credibility and simulation efficiency as well as reducing model complexity.

2. MESOSCOPIC MODELING AND SIMULATION OF LOGISTICS FLOW SYSTEMS

Three classes of simulation models exist, namely continuous, mesoscopic and discrete. Continuous models are based on differential equations and most frequently applied as system dynamics models to reproduce manufacturing and logistics processes (Banks 2005). Discrete event simulation models provide a high level of detail in modeling logistics systems, but can be very complicated and slow, i.e. when it comes to modeling and simulating complex and diverse system structures or incorporating different scenarios (Sterman 2000). In order to overcome the disadvantages of these traditional simulation approaches Reggelin and Tolujew developed the mesoscopic modeling and simulation approach which will be shortly described in this section. For further reading we recommend (Reggelin 2011; Tolujew, Reggelin, and Kaiser 2010; Schenk et al. 2010; Schenk, Tolujew, and Reggelin 2009b). The developed mesoscopic modeling and simulation approach has the following characteristics:

- Less modeling and simulation effort than in discrete event models,
- Higher level of detail than in continuous simulation models,
- Straightforward development of models.

The mesoscopic modeling and simulation approach is situated between continuous and discrete event approaches in terms of level of modeling detail and required modeling and simulation effort (see Fig. 1). It supports quick and effective execution of analysis and planning tasks related to manufacturing and logistics networks.

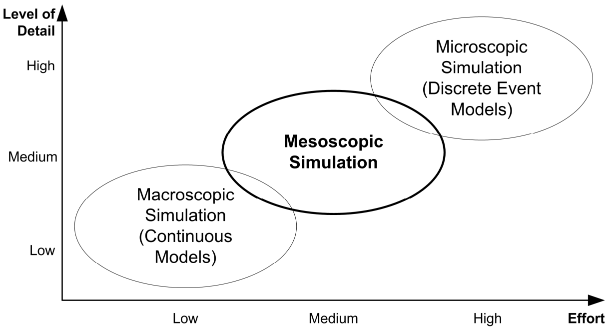

Figure 1: Classification of the mesoscopic simulation approach

This mesoscopic approach is consistent with the principles of the discrete rate simulation paradigm implemented in the simulation software ExtendSim (Krahl 2009; Damiron and Nastasi 2008). Piecewise constant flow rates and the resulting linear cumulative flows support event scheduling and boost computational performance.

Even when the term mesoscopic is not explicitly applied, a mesoscopic view often already exists from the start of flow system modeling and simulation. Many practical analysis and planning problems like capacity planning, dimensioning or throughput analysis describe performance requirements, resources and performance results in an aggregated form that corresponds to a mesoscopic view (cp. Schenk, Tolujew, and Reggelin 2008a). Mesoscopic models are particularly suited for the analysis of large-scale logistics networks and processes with a homogenous flow of a large number of objects. In most cases, the disproportionate amount of computation required would make item-based discrete event simulation overly complex for these applications.
The principles of mesoscopic simulation of logistics processes were derived from several mesoscopic models (Schenk, Tolujew, and Reggelin 2008a; Schenk, Tolujew, and Reggelin 2009a; Schenk, Tolujew, and Reggelin 2008b; Savrasov and Tolujew 2008; Tolujew and Alcalá 2004; Hanisch et al. 2003).

3. CONCEPTUAL MODELING PHASE

The conceptual modeling phase of a simulation study is one of the most important parts (Robinson 2008). In context that good conceptual modeling can significantly contribute to a successful outcome of a simulation study, it still is a difficult and hard to understand stage in the modeling process (Law 1991). Guidelines for the modeling process can be found in (Law 2007; Pidd 1999; Uthmann and Becker 1999).

For conducting a successful simulation study the Seven-Step approach by Law can be applied for mesoscopic simulation (Law 2009). In the conceptual modeling phase step 2 is an important part for determining the level of detail as well as the system and process structure of the model (see Fig. 2). Here, for mesoscopic modeling and simulation an essential and inherent part is the grouping or aggregation of logistics objects.

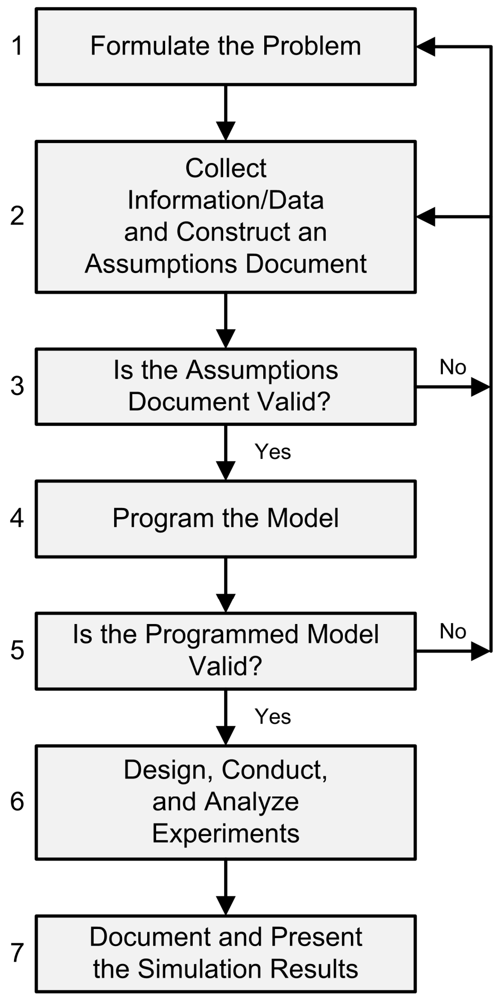

Figure 2: A Seven-Step Approach for Conducting a Successful Simulation Study (Law 2009)

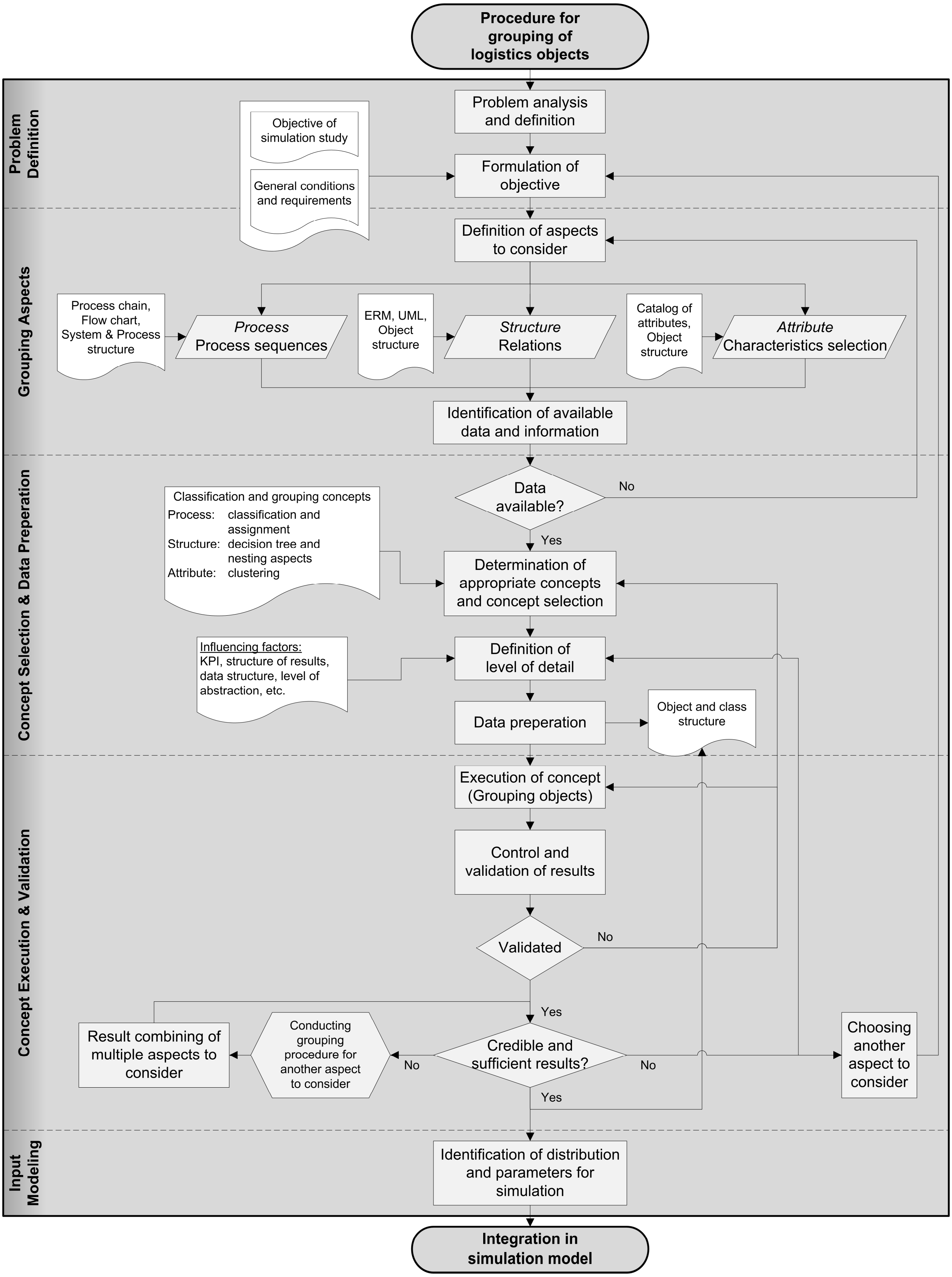

Figure 3: Procedure for grouping of logistics objects

But there is a lack in supporting the composition and decomposition of logical groups of logistics objects. However, this is of significant importance to approach the increasing complexity of logistics systems and processes efficiently. Zeigler et al. also suggest as one method of simplification for simulation modeling to group components of the model (Zeigler, Praehofer, and Kim 2007).

In (Law 2009; Brooks and Tobias 1996; Zeigler, Praehofer, and Kim 2007) guidelines for determining the level of detail of a simulation model can be found. They are also related to the aspect of simplification by grouping objects and elements of the simulation model. However, these guidelines do not provide a clear procedure in how to approach the grouping of objects.

4. CONCEPTUAL PROCEDURE FOR GROUPING OF LOGISTICS OBJECTS

Therefore, to support this step of the conceptual modeling phase a procedure was developed which addresses the effective and credible grouping (aggregation) of logistics objects in context of mesoscopic modeling and simulation (see Fig. 3).

The procedure is based on grouping the considered logistics objects (i.e. products that are processed through logistics systems and processes) according to three aspects that basically determine the relations among objects. This implies the consideration on a process basis, structure basis and/or attribute basis. For conducting the grouping procedure on an attribute basis an attribute catalog will support the process of identifying relevant characteristics of the considered logistics objects. Here, (Koch 2010) presents a first overview of characteristics related to object analyses in the field of logistics. For the aspects of process and structure modeling concepts like Process Chain, Flow Chart or Entity Relationship Model and Unified Modeling Language as well as a system, process and object structure can be used for illustrating and determining the relations (Koch, Tolujew, and Schenk 2012).

The fundamental steps of the procedure are:

- Problem definition
- Grouping aspects
- Concept selection & data preparation
- Concept execution & validation
- Input modeling

The problem definition is based on the problem task and objective of the related simulation study. These aspects have an impact on formulating the objective of the grouping procedure.

The second fundamental step is about defining and choosing the aspect (process, structure or attribute) to be considered for the following steps of the procedure.

After identifying and collecting available data an appropriate grouping concept has to be chosen. Here, methods of multivariate data analysis, in particular classification schemes and clustering methods are to be applied. For the three grouping aspects we propose different grouping concepts (see Fig. 3). Before executing these methods, the respective and wanted level of detail has to be defined. This is one of the most difficult steps of the procedure. A collection of influencing factors for determining the level of detail is presented to support the decision making process. If the results according to the level of detail will not be satisfying the procedure should be repeated.

After preparing the data for the chosen concepts, which will contribute to forming an object structure (see Fig. 4), the grouping method can be applied. In the following step the validation and control of the results according to credibility and sufficiency is conducted. If this is not satisfactory the procedure should be repeated. This even provides the opportunity to combine the results of multiple aspects that were considered.

As a last step there is the process of input modeling for the simulation model which refers to identifying the distributions and parameters of the identified groups out of the data of the considered logistics objects. As a consequence the groups or classes respectively can be then implemented in the simulation model.

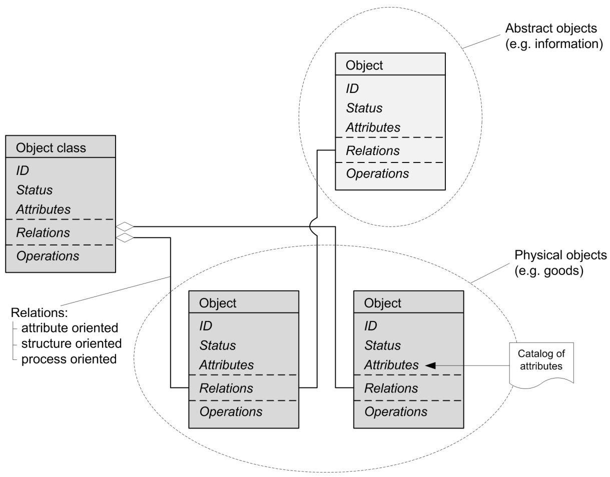

Figure 4: Object and class structure

The complete procedure should be seen as iterative until the wanted and needed results, i.e. groups of logistics objects in an appropriate level of detail, are obtained.

For the mesoscopic simulation approach the identified groups or classes respectively can be implemented as product types in the simulation model. This will reduce model complexity.

5. APPLICATION

The application example is from the field of biomass logistics. Biomass logistics is a relatively young research area which is confronted with challenging planning and problem tasks. This is for example due to the heterogeneity of biomass and the different parties involved in the biomass logistics chain. For further reading we recommend (Trojahn 2011). In order to cope with the identified challenges a grouping of biomass objects and the application of the mesoscopic modeling and simulation approach for logistics flow systems is applied.

Biomass is characterized by a high level of diversity and heterogeneity. In (Reggelin, Trojahn, and Koch 2011) an exemplary overview of characteristics that are relevant to biomass is shown. This provides support for conducting a grouping based on a selection of relevant attributes and characteristics.

In this example we consider a biomass logistics chain consisting of six sequential process steps: consolidation, gasification, power generation (fuel cell) and the related transportation steps as illustrated in Figure 5. The system structure is characterized by three sources of different biomass, i.e. wood, hay and straw, two consolidation points, one gasification facility, one power generation facility as well as two customers.

scenario, which refers to a more diverse and heterogeneous structure of biomass types, clustering methods will provide a high level of support.

At first the different objects or the diverse supply of the biomass types were grouped together according to their general same type or kind of biomass and the related process steps (based on the same source and process sequence). This results in the groups of *Wood*, *Hay* and *Straw*. They also form the input product types of the supply chain. The same procedure was also applied for the product types of *Biogenic Gas* and *Power*. In grouping objects of the same type or kind respectively together a transparent and credible result is attained and presented.

Second, the structure of the system and the processes of the considered biomass supply chain allow

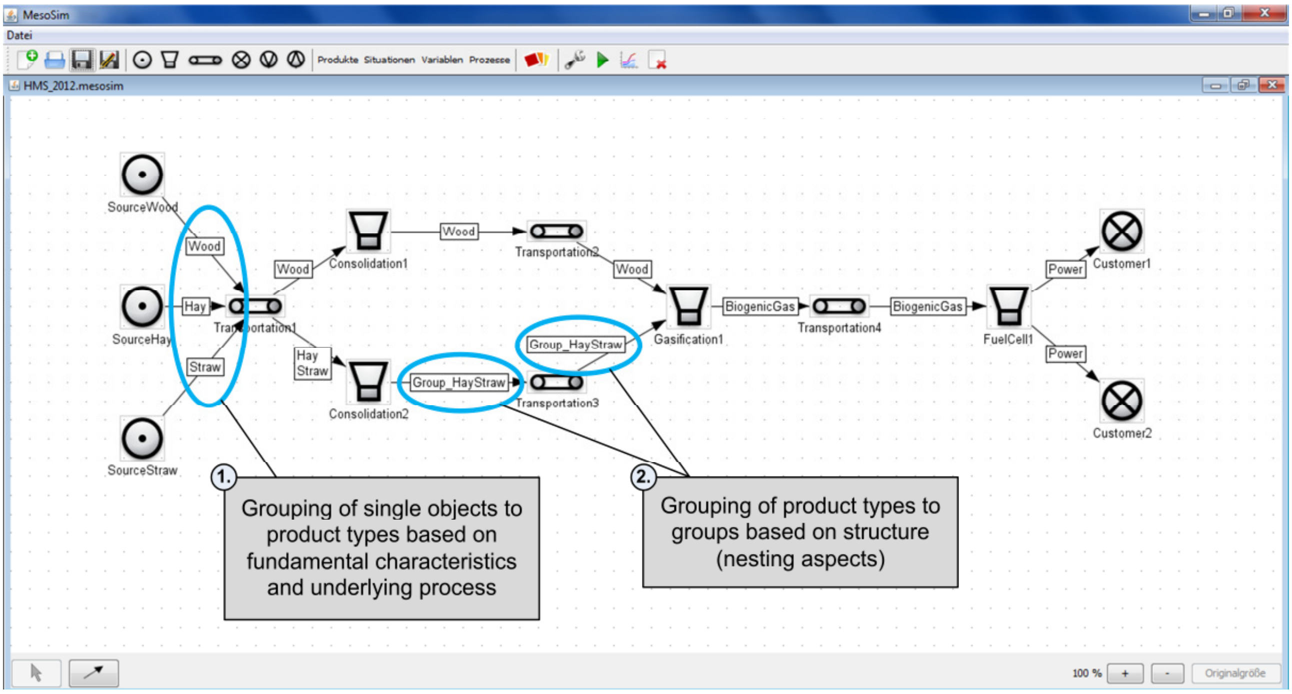

Figure 5: A mesoscopic model of a biomass logistics chain with MesoSim

The mesoscopic simulation model of the considered biomass logistics chain shown in Figure 5 was created with the simulation software MesoSim. This tool was developed by Reggelin and Tolujew (Reggelin 2011) in order to facilitate an easy and direct implementation and computation of mesoscopic simulation models.

For grouping the biomass logistics objects as a significant part of the conceptual modeling phase the proposed grouping procedure is applied. In the following the key aspects of the presented grouping procedure are explained. For demonstration purposes an example of only three different types of biomass was chosen.

For grouping the different biomass logistics objects the aspects of process and structure were chosen (see Fig. 5), due to the fact that information about attributes were limited and conducting a clustering process would not add significant benefit because of the simplicity of the example. However, in case of a more complex

a further grouping of the product types related to nesting aspects. In using the same transportation means the product types *Hay* and *Straw* can be grouped together in sections forming the product type *Group_HayStraw*. This means a reduction of product types for this part of the supply chain that need to be considered during the simulation run.

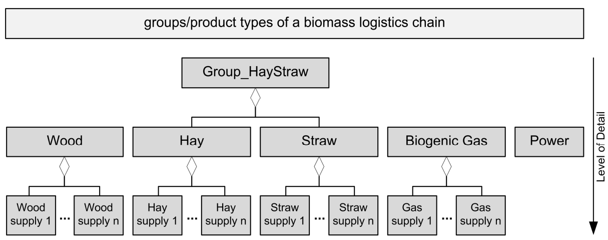

Figure 6: Grouping hierarchy of an exemplary biomass logistics chain

Figure 6 shows again the grouping hierarchy of the application example. This simple object and class structure allows the implementation of different aggregation levels into the simulation model which has a direct impact on defining the level of detail for the simulation model according to the object level. Hereby it is important to choose an amount of product types or a level of detail respectively that is appropriate in context of the problem definition. A higher level of detail will contribute to a higher simulation effort.

In grouping the logistics objects together with the help of the proposed procedure the amount of entities that need to be considered for computations in the simulation run can be reduced. This has a positive effect on the simulation effort without neglecting aspects of transparency and credibility that impact model accuracy and validity.

6. CONCLUSION

The paper describes the challenges that are incorporated with the increasing complexity of logistics systems and processes. This complexity is mainly caused by the increasing diversity and heterogeneity of the logistics objects, i.e. the goods processed through the logistics system. Therefore methods for simplification are needed. Zeigler et al. also suggest as one method of simplification for simulation modeling to group components of the model (Zeigler, Praehofer, and Kim 2007).

Here, the mesoscopic modeling and simulation approach requires support in grouping logistics objects for simplification purpose in an effective and representative way, because there is a lack in supporting the composition and decomposition of logical groups of logistics objects. However, this is of significant importance to approach the increasing complexity of logistics systems and processes efficiently.

Therefore, the paper presents such a procedure for grouping logistics objects in an efficient way supporting the determination of the right and appropriate level of detail for the simulation model and the considered problem task and logistics system. The benefits and effects of the presented grouping procedure as well as its relevance to the field of logistics were demonstrated by an application example in the field of biomass logistics.

The described procedure shall form a part of the conceptual modeling process according to the mesoscopic simulation approach supporting the modeler in the decision making process and contributing to a transparent, effective and qualitative conceptual modeling phase.

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ANALYSING THE EFFICIENCY OF AN INTERMODAL TERMINAL USING SIMULATION

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ABSTRACT
For intermodal transport to be competitive with road haulage, it is of importance that the transferring of transport units happens efficiently. Therefore, in this paper, the working of an intermodal terminal is analysed using a simulation model. The focus is on a rail-road freight transport terminal. To analyse the impact of several input factors on the efficiency of the terminal, an experimental design is set up. The results of the simulation study show that the number of containers and the number of handling equipment are the most important variables. The arrival pattern of trucks has almost no influence on the output measures.

Keywords: simulation, experimental design, rail-road terminal

1. INTRODUCTION

Intermodal freight transport has received increased attention due to problems of road congestion, environmental concerns and traffic safety. Intermodal transportation means that the primary transport is performed by alternative transport modes like rail, barge or sea, while the secondary pre- and post-transport goes by road and is as short as possible (Macharis and Verbeke 1999). Transferring the transport units between the different transport modes is inevitable in intermodal transport. This transferring takes place in terminals. The terminals provide the space, the equipment and the operational environment for transferring intermodal transport units between the different transport modes. For intermodal transport to be competitive with road haulage, it is of importance that the transferring of transport units happens efficiently. Therefore, in this paper, the working of an intermodal terminal is analysed using a simulation model. The focus is on a rail-road freight transport terminal.

The paper is organized as follows. In section 2, a literature review on factors influencing the efficiency of a container terminal is given. In section 3, the simulation study is described. Finally, section 4 formulates conclusions and possible directions for future research.

2. LITERATURE REVIEW

Based on literature, the decisions that influence the efficiency of a container terminal can be divided in three categories, depending on the time horizon: strategic decisions, tactical decisions and operational decisions (Caris et al., 2008).

2.1. Strategic decisions

Long term, strategic planning involves the highest level of management and requires large capital investments over long time horizons. Decisions at this planning level affect the design of the physical infrastructure network. At the strategic level, the location of the terminal, the service area of the terminal, the potential volume of the terminal and the design of the terminal are important factors that influence the efficiency of the terminal. Table 1 gives an overview of these strategic factors and the relevant references. In the remainder of this section, the references that are most relevant for our research, are discussed.

A terminal is ideally located in an area where a lot of production and consumption of goods takes place. Other factors determining the location of a terminal are the location of distribution centers, antagonistic terminals and the access to the main rail and road networks (Ballis and Golias, 2002). Methods for determining the location of a terminal are often based on economic factors, environmental factors or quality aspects (Bergqvist and Tornberg (2008).

The service area of a terminal is the area in which intermodal transport is competitive with road transport (Limbourg and Jourquin, 2010). It is important to know the service area of a terminal in order to determine the potential volume of a terminal.

Once the potential volume of a terminal is known, the layout of the terminal can be determined. Bottani and Rizzi (2007) propose a model to predict the potential volume based on the distance between origin and destination, the time from origin to terminal or from terminal to destination, and the suitability to transport the goods in containers.

Finally, the design of a terminal is an important factor influencing the efficiency of the terminal. Ballis and Golias (2002) indicate the utilization of the tracks, the length of the tracks and the access to the terminal as important factors determining the design of a terminal.

Table 1: Literature review: strategic planning

Strategic Planning		
Factors	Terminal location	Arnold et al., 2004; Benson et al., 1994; Bergqvist & Tomberg, 2008; Limbourg & Jourquin, 2009; Ballis & Golias, 2002
	Service area	Limbourg & Jourquin, 2010; Niérat, 1997
	Potential volume	Bottanis & Rizzi, 2007
	Design	Ballis & Golias, 2002

2.2. Tactical decisions

Medium term, tactical planning aims to ensure, over a medium-term horizon, an efficient and rational allocation of existing resources in order to improve the performance of the whole system. Important factors at the tactical level are the number and type of handling equipment, gantry crane operation modes, train loading/unloading operations and the stacking of containers. Table 2 gives an overview of these tactical factors and the relevant references. In the remainder of this section, the references that are most relevant for our research, are discussed.

A variety of handling equipment exists in the intermodal transport market. Reachstackers and gantry cranes seem to dominate among conventional equipment. Simulation results show that a limited number of fast ‘servers’ gives better service times than a larger number of slow ‘servers (Ballis and Golias, 2002).

Marin Martinez et al. (2004) present a simulation model and modeling approach to the transfer of cargo between trains at rail terminals. Four operation modes for the crane to transfer containers between two trains are proposed: parallel, zigzag, parallel (II) and unloaded train. Based on the results of their simulation study, it can be concluded that the parallel operation mode performs worst in all situations, and the unloaded-train operation performs the best.

Train loading/unloading operations play an important role in determining terminal performance (Ballis and Golias, 2002). Figure 1 shows typical train loading/unloading operations. Four phases can be distinguished and are indicated on the horizontal axis. In the first phase, usually following arrival of the train, direct transshipments from wagon to truck are carried out. After some time, truck arrival rate falls and the handling equipment is using the idle times to transship load units to the storage area. The third phase is pure wagon to store transshipment because no trucks are available in the terminal. In the fourth phase, the trucks that arrive are loaded indirectly from store.

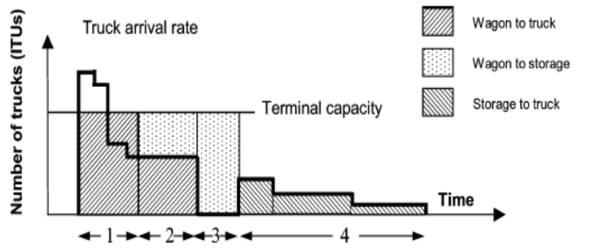

Figure 1: Typical four crane phases of crane work.

The stacking of containers reduces storage requirements and mean travel distance but it increases handling activities (Ballis and Golias, 2002).

Table 2: Literature review: tactical planning

Tactical planning		
Factors	Handling equipment	Ballis & Golias, 2002; Kozan, 2006; Vis, 2006
	Gantry crane operation modes	Marín-Martínez et al., 2004
	Loading/unloading operations	Ballis & Golias, 2002
	Stacking of containers	Ballis & Golias, 2002

2.3. Operational decisions

Short term, operational planning is performed by local management in a highly dynamic environment where the time factor plays an important role. At the operational level, important factors influencing the efficiency of the terminal are the crane area and the load plan of the trains (allocation of containers to wagons). Table 3 gives an overview of these operational factors and the relevant literature. In the remainder of this section, the references that are most relevant for our research, are discussed.

Cranes are often a bottleneck in the handling of containers. Therefore, the determination of a crane area is an important operational factor for the efficiency of an intermodal rail terminal. This crane area can be static (every crane has its own area) (Boysen and Fliedner, 2010) or dynamic (no fixed borders) (Alicke, 2002).

The purpose of a load plan is to transship the containers in such a way that the number of handlings or the time is minimized. The throughputtime of a container is optimized when containers can be loaded from train to truck (or from truck to train). Double handling should be avoided as much as possible (Corry and Kozan, 2006).

Table 3: Literature review: operational planning

Operational planning		
Factors	Crane area	Alicke, 2002; Boysen & Fliedner, 2010; Linn & Zhang, 2003
	Load plan of trains	Bostel & Dejax, 1998; Corry & Kozan, 2006

3. SIMULATION STUDY

3.1. Introduction

A simulation model representing a rail-road freight transport terminal is built in Arena. The simulation model is based on data obtained from the terminal Mainhub in Antwerp and data obtained from literature. Three entity types are considered in the model: containers (both import and export containers), wagons and trucks.

Importcontainers arrive in the terminal by train. The train takes place on the unloading track and the train in unloaded. A gantry crane is used to unload the containers from the train. First, the containers are stored in the storage zone next to the tracks. When a reach stacker is available, the container is moved to a different storage zone. Here the container will be stored until a truck arrives.

For export containers, which reach the terminal by truck, the steps are similar to the import container, but in the reverse order.

When a truck arrives at the terminal, first a distinction is made between a truck that comes to pick up a container and a truck that delivers a container. If a truck comes to pick up a containers, the truck is loaded using a reach stacker. If the truck comes to deliver a container, the truck waits next to the loading track until an empty wagon is available. Then the container is loaded on the train using a gantry crane.

A simulation of 24 hours is run. 10 replications are made for each configuration of the simulation model.

3.2. Design of experiments

To analyse the impact of several input factors on the efficiency of the terminal, an experimental design is set up. Four input factors are considered: the number of containers, the number of handling equipment (reachstackers and cranes) and the arrival pattern of trucks.

For each of the input factors, two levels are considered. The number of containers handled (factor 1) equals 300 containers a day for the lower level and 750 containers a day for the upper level. These levels are based on Ballis and Golias (2004).

Since reachstackers and gantry cranes are the handling equipment that is mostly used in rail terminals, the number of these two types of handling equipment are used as input factors in the experimental design. Based on data of the Belgian terminals, the two levels for the number of cranes (factor 3) are set to 1 and 2. Small terminals in Belgian have maximum one crane, while big terminals in Belgian have 2 of 3 cranes. The mean number of reach stackers in a Belgian terminal is around 3. Therefore, the two levels for the number of reach stackers (factor 2) are set to 2 and 4.

Two types of arrival patterns for the trucks (factor 4) are considered: all trucks arrive in a small timespan or the trucks arrive spread over a large timespan.

Concerning the output measures of the system, it is important to have a look at both the efficiency of the system and the profitability of the system. As output measures the utilization of handling equipment, the throughput time of containers and the profit of the system are calculated.

A full factorial design is used, table 4 gives an overview of the 16 experimental points.

Table 4: Experimental design

	Containers	Reach-stackers	Cranes	Arrival pattern
1	300	2	1	Close
2	300	2	1	Spread
3	300	2	2	Close
4	300	2	2	Spread
5	300	4	1	Close
6	300	4	1	Spread
7	300	4	2	Close
8	300	4	2	Spread
9	750	2	1	Close
10	750	2	1	Spread
11	750	2	2	Close
12	750	2	2	Spread
13	750	4	1	Close
14	750	4	1	Spread
15	750	4	2	Close
16	750	4	2	spread

3.3. Main simulation results and discussion

The results of the simulation study are shown in Table 5. For each of the output measures, confidence intervals for the main and interaction effects are given.

Significant effects are indicated in italic. Eight of the eleven significant effects are main effects.

The results indicate that the number of containers, the number of reachstackers and the number of cranes are significant variables. The arrival pattern of trucks has no significant influence on the output measures.

The utilization of the reachstackers is significantly influenced by the number of containers handled and the number of reachstackers. The higher the number of containers handled in the terminal, the higher the utilization of the reachstackers. The higher the number of reachstackers in the terminal, the lower the utilization of the reachstackers.

The utilization of the cranes is significantly influenced by the number of containers handled and the number of cranes in the terminal. The higher the number of containers handled, the higher the utilization of the cranes. The higher the number of cranes the terminal, the lower the utilization of the cranes.

The troughputtime of an exportcontainer depends on the number of cranes in the terminal. When the number of cranes is higher, the throughputtime of the container is lower.

The troughputtime of an importcontainer depends on the number of reachstackers in the terminal. When the number of reachstackers is higher, the throughputtime of the importcontainer is lower.

The profit of the container terminal is significantly influenced by the number of containers handled and the number of reachstackers. The more containers are handled in the terminal, the higher the profit of the terminal. The more reachstackers the terminal uses, the lower the profit of the terminal. One would expect here that the number of cranes also has an influence on the profitability of the terminal. However, although this effect is asymmetric, no significant effect is found.

Based on the results, it can be stated that both the number of containers handled as the number of handling equipment has an influence on the output measures. When both the throughput time and the utilization of the equipment are high, new equipment can be necessary. When the terminal is handling mostly import containers, a reach stacker is the best option. When export containers are mostly handled by the terminal, a crane is the best option.

4. CONCLUSIONS AND FUTURE RESEARCH

For intermodal transport to be competitive with road haulage, it is of importance that the transferring of transport units happens efficiently. Therefore, in this paper, the working of an intermodal terminal is analysed using a simulation model. The focus is on a rail-road freight transport terminal.

Based on literature, the decisions that influence the efficiency of a container terminal are described. At the

Table 5: Main and interaction effects for the output measures (1)

Effect	Utilization reachstackers	Utilization cranes
1	*[0,16;0,24]*	*[0,18;0,25]*
2	*[-0,19;-0,13]*	[-0,006;0,01]
3	[-0,05;0,05]	*[-0,21;-0,13]*
4	[-0,05;0,03]	[-0,03;0,02]
1-2	*[-0,10;-0,04]*	[-0,01;0,009]
1-3	[-0,04;0,04]	*[-0,12;-0,03]*
1-4	[-0,07;0,04]	[-0,05;0,03]
2-3	[-0,04;0,04]	[-0,03;0,04]
2-4	[-0,04;0,06]	[-0,03;0,03]
3-4	[-0,05;0,05]	[-0,02;0,03]
1-2-3	[-0,03;0,03]	[-0,02;0,03]
1-2-4	[-0,06;0,08]	*[-0,10;-0,03]*
1-3-4	[-0,04;0,05]	[-0,04;0,05]
2-3-4	[-0,04;0,07]	[-0,03;0,04]
1-2-3-4	[-0,04;0,05]	[-0,03;0,04]

Table 6: Main and interaction effects for the output measures (2)

Effect	Throughput-time export container	Throughput-time import container
1	[-0,81;0,25]	[-0,44;1,80]
2	[-0,65;0,53]	*[-1,17;-0,04]*
3	*[-1,88;-0,68]*	[-1,44;0,33]
4	[-0,59;0,71]	[-0,84;0,91]
1-2	[-0,60;0,53]	[-0,99;0,03]
1-3	*[-2,01;-0,17]*	[-1,18;0,14]
1-4	[-0,74;0,40]	[-1,01;0,66]
2-3	[-0,63;0,83]	[-1,02;0,68]
2-4	[-0,43;0,68]	[-0,62;1,18]
3-4	[-0,59;0,99]	[-0,71;0,88]
1-2-3	[-0,40;0,49]	[-0,69;0,30]
1-2-4	*[0,49;1,68]*	[-0,84;1,17]
1-3-4	[-1,32;1,13]	[-0,75;0,73]
2-3-4	[-0,57;0,54]	[-0,64;0,85]
1-2-3-4	[-0,21;0,64]	[-0,75;0,86]

Table 7: Main and interaction effects for the output measures (3)

Effect	Profit
1	*[1.920.153,74;2.381.120,47]*
2	*[-395.669,28;-132.454,14]*
3	[-785.502,12;185.869,46]
4	[-273.580,85;123.522,64]
1-2	[-151.061;89.402]
1-3	[-395.601;349.174,2]
1-4	[-362.876;259.788,7]
2-3	[-307.231;330.472]
2-4	[-246.128;239.357]
3-4	[-300.170;250.257,7]
1-2-3	[-319.277;315.376,6]
1-2-4	[-314.108;237.050]
1-3-4	[-300.028;303.073,3]
2-3-4	[-250.496;397.690,4]
1-2-3-4	[-247.621;295.394,1]

strategic level, the location of the terminal, the service area of the terminal, the potential volume of the terminal and the design of the terminal are important factors that influence the efficiency of the terminal. Important factors at the tactical level are the number and type of handling equipment, gantry crane operation modes ,train loading/unloading operations and the stacking of containers. At the operational level, important factors influencing the efficiency of the terminal are the crane area and the load plan of the trains (allocation of containers to wagons).

A simulation model representing a rail-road freight transport terminal is built in Arena. To analyse the impact of several input factors on the efficiency of the terminal, an experimental design is set up. Four input factors are considered: the number of containers, the number of handling equipment (reachstackers and cranes) and the arrival pattern of trucks (all trucks arrive in a small timespan or the trucks arrive spread over a large timespan). As output measures the utilization of the handling equipment, the throughput time of the containers and the total costs of the system are calculated.

The results of the simulation study show that the number of containers and the number of handling equipment are the most important variables. The arrival pattern of trucks has almost no influence on the output measures. When both the throughput time and the utilization of the equipment are high, new equipment can be necessary. When the terminal is handling mostly import containers, a reach stacker is the best option. When export containers are mostly handled by the terminal, a crane is the best option.

The simulation model in this paper is mainly based on the literature review. However, in future research, the model could be refined based on the practical, real-life working of a rail-road container terminal. Based on this practical information, other input factors and/or output measures can also be added to the experimental design and advice could be given to improve the working of the terminal.

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TRANSFORMER MODELING TAKING INTO ACCOUNT HYSTERESIS BEHAVIOR

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ABSTRACT
An efficient and precise finite network model to simulate the dynamic behaviour of transformer core laminations is presented. The model considers both hysteresis and eddy current losses and is based on an electric and magnetic circuit connected by a gyrator. This approach allows to easily include the classical Preisach operator to take into account hysteresis and saturation behaviour. The eddy current losses are modelled with an additional inductance in the magnetic circuit. Simulation results are in good agreement with measurements of a single phase and three phase transformer as used in power-supply systems.

Keywords: Preisach Model, Hysteresis, Transformer

1. INTRODUCTION

The design of energy-efficient power transformers and electric power systems requires a mathematical model of sufficient complexity (Jungwirth, Baumgartinger, and Kaltenbacher 2010). In case of fault detection the phenomenon of inrush current in transformers has been known for many years, and discussed in many studies (Akcay and Ece 2003; Casoria, Sybille, and Brunelle 2003; Chen, Lin, and Cheng 2005; Theocharis, Milias-Argitis, and Zacharias 2008). The well-known linear transformer model does not take the effects of saturation, hysteresis and eddy currents into consideration. However, these nonlinearities significantly influence the behavior of a transformer during switching-on and restart as well as other types of transients (Akcay and Ece 2003).

The current research work was motivated from the objective of precisely estimating the dynamic behavior of transformers, and therefore hysteresis, saturation and eddy currents are taken into account. The parameters for our model are determined form measurements performed on an Epstein frame or/and directly on the transformer cores itself, and the SimPowerSystems-Toolbox in MATLAB/Simulink is used as simulation environment. The developed model is applied to a single phase and a three phase transformer.

2. TRANSFORMER

2.1. Ideal Transformer Model

A transformer is an electric device that transfers energy from one circuit to another. The two circuits are coupled by a magnetic field, which is mainly concentrated within the iron core. The simplest model considers this iron core as ideal. This means that the transformer has no losses, and so the energy transfer from the primary side to the secondary side is perfect.

A transformer consists of the primary side with N_1 windings and the secondary side with N_2 windings. If a time-varying voltage u_1 is applied to the primary side, a current will flow and produces a magnetomotive force (MMF). The MMF drives the varying magnetic flux ϕ_1 through the iron core and induces a back electromotive force (EMF) in opposition to u_1. In accordance with Faraday's law, the voltage induced across the primary winding is proportional to the rate of change of flux

$$u_1 = N_1 \frac{d\phi_1}{dt}. \tag{1}$$

Therefore, the voltage induced across the secondary winding is

$$u_2 = N_2 \frac{d\phi_2}{dt}. \tag{2}$$

If and only if a perfect flux coupling is available, the flux on the primary side will be equal to the flux in the secondary side. So we can equate ϕ_1 and ϕ_2 and obtain the following fundamental relation

$$\frac{u_1}{u_2} = \frac{N_1}{N_2} = \frac{i_2}{i_1} = \ddot{u}. \tag{3}$$

2.2. Non-Ideal Transformer model

For a realistic transformer model we have to consider the magnetic resistance of the iron core and its losses (Hagmann 2001). The losses can be represented by an iron loss resistance R_{Fe} in parallel with the main impedance L_{H}, see Fig. 2. The resistance characterize the iron core losses and the impedance describes the magnetizing current I_μ which maintains the mutual flux in the core. The sum of the magnetizing current and the current through the resistance R_{Fe} describes the unloaded transformer with the no-load current I_{10}.

Furthermore, the windings of the transformer are magnetically non-ideal coupled with each other, which results in flux leakage as shown in Fig. 1.

This can be modeled as reactances of each leakage inductance $L_{\sigma 1}$ and $L_{\sigma 2}$. Taking into account the power

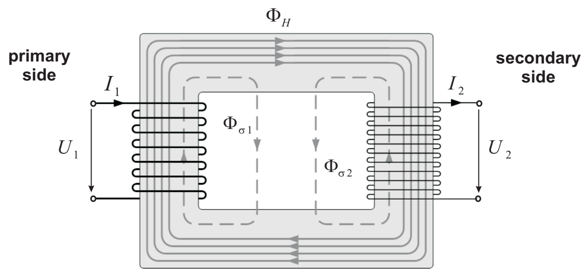

Figure 1: Flux Leakage in a Transformer.

loss in the windings R_1 and R_2, which are represented as in-series resistances to the leakage inductances, the equivalent circuit diagram of a real transformer is displayed in fig 2.

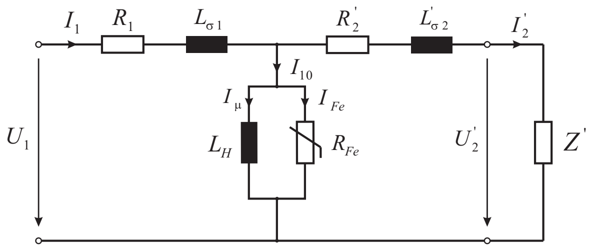

Figure 2: Equivalent Circuit Model for the Non-Ideal Transformer.

All elements on the secondary side can be converted to the primary side using (3). Therefore, $R_2^{'}$, $L_{\sigma 2}^{'}$, $I_2^{'}$, $U_2^{'}$ and $Z^{'}$ compute as

$$R_2^{'} = \ddot{u}^2 R_2 \tag{4a}$$

$$L_{\sigma 2}^{'} = \ddot{u}^2 L_{\sigma 2} \tag{4b}$$

$$I_2^{'} = \frac{1}{\ddot{u}^2} I_2 \tag{4c}$$

$$U_2^{'} = \ddot{u}^2 U_2 \tag{4d}$$

$$Z^{'} = \ddot{u}^2 Z\,. \tag{4e}$$

2.3. Transformer Equations for Inrush Currents

The general solution of the differential equation for the primary side of the single-phase transformer is

$$u_1 = R_1 i_1 + L_{\sigma 1}\frac{di_1}{dt} + \frac{d\psi}{dt}\,, \tag{5}$$

where ψ denotes the total linked flux, which computes as

$$\psi = N\phi = L_{\mathrm{H}} i_{\mu}\,. \tag{6}$$

Inserting (6) into (5) results in

$$u_1 = R_1 i_1 + L_{\sigma 1}\frac{di_1}{dt} + i_{\mu}\frac{dL_{\mathrm{H}}}{dt} + L_{\mathrm{H}}\frac{di_{\mu}}{dt}\,. \tag{7}$$

Therefore, neglecting the leakage flux ($L_{\sigma 1}\frac{di_1}{dt}$), and the iron loss resistance (R_{Fe}) simplifies (7) to

$$u_1 = R_1 i_1 + L_{\mathrm{H}}\frac{di_{\mu}}{dt}\,. \tag{8}$$

This relation will be used in the simulation to determine the inrush currents.

3. PREISACH MODEL

Various methods have been proposed for modeling hysteresis (Mayergoyz 2003; Visintin 1994; Krasnoselskii and Pokrovskii 1989). However, due to its universality, the most practical approach to model hysteresis behavior is provided by the Preisach operator. Mayergoyz was the first who described a method to identify the density function for the Preisach operator in the proof of his characterization theorem (for details, see (Mayergoyz 2003)). The important weight matrix, which is computed by the density function, is based on data supplied from manufacturers and/or obtained from defined measurements, e.g., by an Epstein frame.

3.1. Basic definitions

In the following section, we will describe the Preisach operator, and discuss its properties. Let's consider the non-ideal relay operator $\gamma_{\alpha\beta}$ which is characterized by its threshold values $\alpha > \beta$. Its output $\gamma_{\alpha\beta}$ can take the values 0 or 1 where α is the 'ON switch' and β the 'OFF switch' of the operator. The dynamics of the relay are illustrated by Fig. 3.

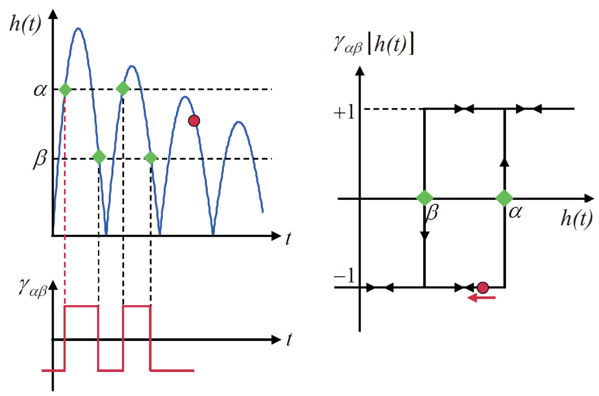

Figure 3: Simplest Hysteretic Operator.

The values of the output of $\gamma_{\alpha\beta}$ at a moment t_k are defined by the following explicit formula:

$$\gamma_{\alpha\beta}[h(t_k)] = \begin{cases} +1 & h(t_k) > \alpha, \\ \gamma_{\alpha\beta}[h(t_k - 1)] & \beta > h(t_k) > \alpha, \\ -1 & h(t_k) < \beta. \end{cases} \tag{9}$$

where $h(t_k)$ is the input value at time t_k.

The main assumption made in the Preisach model (Mayergoyz 2003) is that the system can be thought of as the parallel summation of a continuum of such weighted non ideal relays $\gamma_{\alpha\beta}$, where the weighting of each relay is $\wp(\alpha,\beta)$. Such a summation can be uniquely represented as a collection of non-ideal relays as points on the two-dimensional half-plane $S = \{(\alpha,\beta) \in \mathbb{R}^2 | \alpha \geq \beta\}$. This is also known as the Preisach plane and is displayed in Fig. 4. Here the area S^+ is the set of the threshold values (α,β) for which the corresponding relays $\gamma_{\alpha\beta}$ are switched on at a given moment t. The output of the Preisach model $\mathscr{H}(t)$ then computes as

$$\mathscr{H}(t) = B(t) = B_s \iint_S \wp(\alpha,\beta)\gamma_{\alpha\beta}[h(t_k)]\, d\alpha d\beta, \quad (10)$$

where B_s is the maximum flux density at saturation. The Preisach model works only between $+1$ and -1, so the flux density B_s is a scaling factor of the original values. Also the input value is normalized by $h(t) = H(t)/H_s$. Both, B_s and H_s are from real measurements.

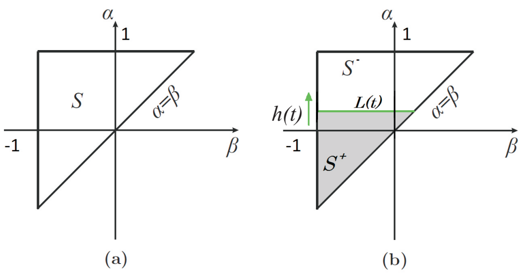

Figure 4: Preisach Plane

To reduce numerical effort, the Everett function is introduced

$$\mathscr{E}(h_{N-1},h_N) = sign(h_{N-1},h_N) \iint_{T_{h_{N-1},h_N}} \wp(\alpha,\beta) d\alpha d\beta\,, \quad (11)$$

which leads to the final formulation

$$\mathscr{H}(h) = \mathscr{E}(-h_0,h_0) + \sum_{k=1}^{N} \mathscr{E}(h_{k-1},h_k). \quad (12)$$

3.2. Graphical Representation

A illustrative graphical representation can be found in (Hegewald 2008) and will be used in this section. In Fig. 5 it is demonstrated how the operators $\gamma_{\alpha\beta}$ switch according to a specific input function $h(t)$. In the beginning all $\gamma_{\alpha\beta}$ are reset to 0. For a rising slope of $h(t)$, the $\gamma_{\alpha\beta}$ with the property $\alpha < h(t)$ are set to 1. For a falling slope of h(t), the $\gamma_{\alpha\beta}$ with the $\beta > h(t)$ are reset to -1. This divides the Preisach plane S into one part with activated switching operators ($S+$) and another part containing deactivated operators ($S-$). The evaluation of the integral in (10) results in the hysteresis curve given in Fig. 5.c.

3.3. Weight Function and Identification Procedure

As already mentioned, the Preisach weight function defines the shape of the hysteresis curve and, therefore, has to be adapted to measured data. In principle, there are two different methods. One possibility is to discretize the Preisach plane, which results in a finite number of weights $\wp(\alpha,\beta)$ that have to be identified. The other approach suggests an analytical function $\wp_A$ with a small number of parameters to express the continuous weight function $\wp(\alpha,\beta)$. In the literature, e.g., (Consolo, Finocchio, Carpentieri, Cardelli, and Azzerboni 2006), a so called Lorentzian function with four parameters A, h, A_1 and A_2 can be mainly found.

3.3.1. Discretized Preisach Weights

Now, the identification problem is to determine the Preisach weights $\wp(\alpha,\beta)$. It has been shown in (Mayergoyz 2003), that this task can be solved by a family of symmetric minor loops. The first step is to discretize the Preisach plane into M supporting points. The supporting points are also responsible for the dimension of the weight matrix. The amount of discretization points in the Preisach plane is $n_{\wp} = \frac{1}{2}M(M+1)$. Figure 6 demonstrates the identification procedure.

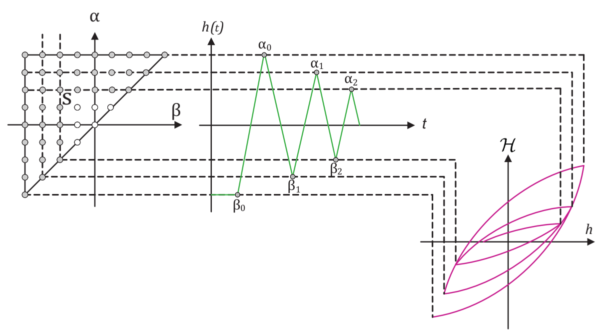

Figure 6: Parameter Identification Procedure $\wp$ With (M=9) Supporting Points. The Gray Points in the Preisach Plane (On the Left Side) are Already Identified.

More discretization points means more of the symmetric minor loops to identify all of the reversal points α_1 to α_M and β_1 to β_M. Now, the discrete Preisach operator reads as

$$\mathscr{H} = \sum_{\lambda \in \Lambda} a_\lambda \mathscr{H}_\lambda \quad (13)$$

with $\mathscr{H}_\lambda$ the simple relay operator having switching levels (α,β). The amount of Λ consists of the index pairs (i,j) to characterize all switching thresholds α_i, β_j in the Preisach plane. By solving the least squares problem (Kaltenbacher and Kaltenbacher 2007)

$$\min \sum_{k=1}^{n_\top} \left(\sum_{\lambda \in \Lambda} a_\lambda \mathscr{H}_\lambda[h_k] - B_k \right)^2 \quad (14)$$

with $n_\top$ the number of measurement points, we obtain the discrete Preisach weights. The advantage of this approach is that there exist distinct mathematical regulations for the identification of the weights, as described in (Mayergoyz 2003).

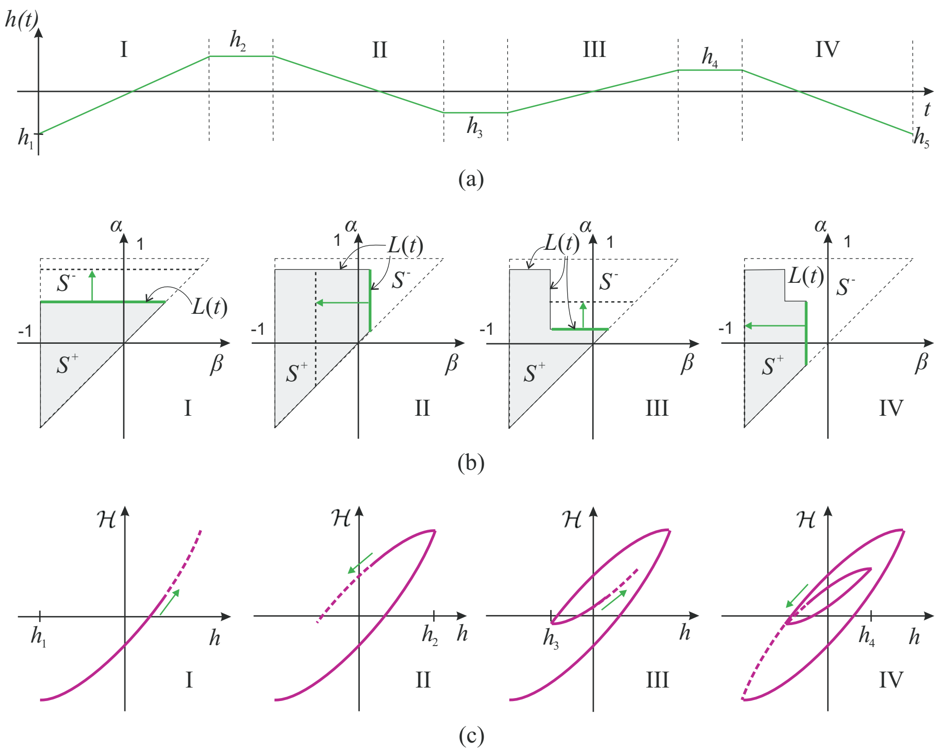

Figure 5: Graphical Representation of the Preisach Operator. (Hegewald 2008)
(a): Example of the Time Behavior of an Input Signal $h(t)$,
(b): Preisach Plane With Activated ($S+$) and Not Activated ($S-$) Switching Operators,
(c): Resulting Hysteresis Curve.

3.3.2. Analytical Weight Function

As already mentioned before, a second method to express the weights $\wp(\alpha\beta)$ is an analytical function with a small number of parameters. We apply a Lorentzian weight function with four parameters $A, h, A1$ and $A2$. This analytical weight function can be further improved with help of an additional parameter η, which forms the corners of the hysteresis loop and makes the function suitable for a wide range of harder and softer magnetic materials (Sutor, Rupitsch, and Lerch 2010). Therewith, we arrive at the following analytical expression

$$\wp_{DAT}(\alpha,\beta) = \frac{A}{1+(((\alpha+\beta)\sigma_1)^2+((\alpha-\beta-h(t_k))\sigma_2)^2)^\eta} \quad (15)$$

The parameters are obtained by applying the least-square curve fitting method using the optimization toolbox of Matlab.

4. EPSTEIN APPARATUS

The identification of the Preisach weights for the specific materials used in the transformer cores are based on measurements using an Epstein apparatus. The '25cm' Epstein apparatus consists of 4 coils with primary windings, secondary windings and the material sample as core. The sheets are stratified in stripes. The measurement setup represents in this way a transducer, whose characteristics are specified. The primary outer windings (N_1) are used to magnetize the material and the secondary inner windings (N_2) are needed for magnetic flux density determination over the induced voltage U_2. As the magnetic quantities are not measurable directly, the physical correct conversion into electric quantities must be guaranteed through the transducer principle. The steel sheet specimens are part of the transducer. For further details about this device and the measurement setup, please refer to the norm of the European Committee for Standardization (CEN) (CENELEC 2009).

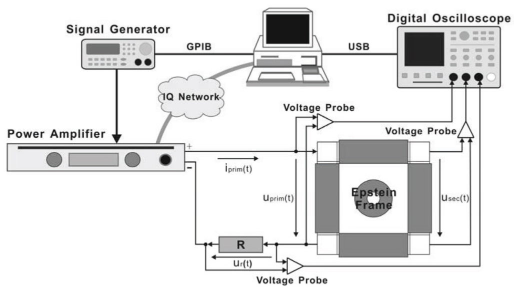

Figure 7: Epstein Setup for Measurements of Outer and Inner Hysteresis Loops.

5. FINITE NETWORK MODEL OF POWER TRANSFORMERS

Modeling magnetic components for use in circuit simulations can take several forms. The first approach, which is

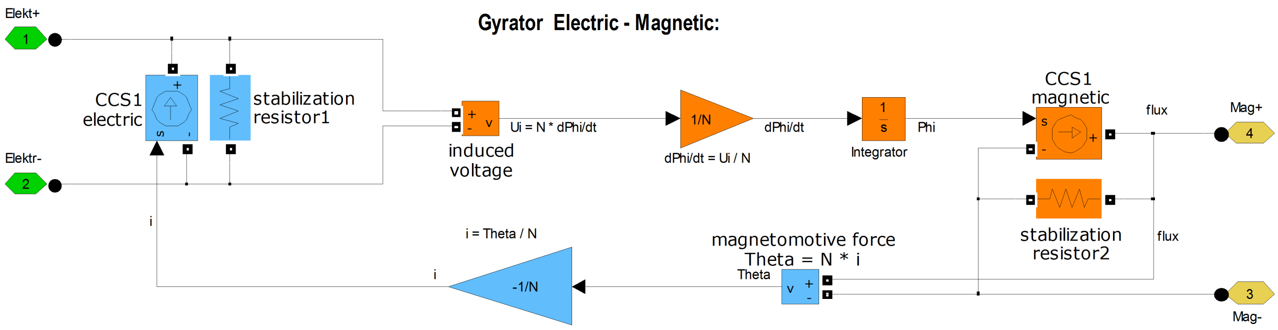

Figure 8: Gyrator in Integral Form.

generally used, models each magnetic component as an ideal, linear component, using inductors with coupling coefficients to represent common flux paths. This can be extended to include nonlinear and even hysteretic couplings to model nonlinear and even hysteretic material behavior.

The technique, which we apply, is to decompose the system into two Kirchhoff circuits, one electric and one magnetic circuit (Brown, Ross, and Nichols 2001). Therewith, it is possible to simulate arbitrarily complex, nonlinear, hysteretic magnetic systems in the time domain and furthermore it can be used to consider the eddy currents. The hysteretic behavior of the inductance in the magnetic circuits is modeled by the classical Preisach operator as described in chapter 3.

5.1. Magneto-Electric Gyrator

To couple the electric and magnetic circuit, we use a magneto-electric gyrator as displayed in Fig. 9. This asymmetric component forms the basis of the interface between the magnetic and electric circuit, that allows to "push" devices from circuit to circuit. The dependent and

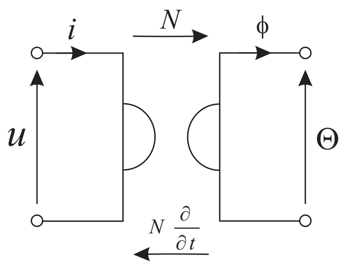

Figure 9: Gyrator to Model the Connection Between the Electric and Magnetic Circuit.

independent variables in the electric network are voltage u and current i and the corresponding variables in the magnetic circuit are magnetomotive force Θ and flux ϕ. Therefore, the compound circuit is solved in terms for u, i, Θ and ϕ.

The components and equations (e.g. $u = Ri, u = Ldi/dt$) to model electric circuits are well known in comparison for modeling magnetic circuits. For this reason it is easier to transform components from the magnetic to the electric domain or vice versa. For example, the magnetic inductor is the magnetic analog of a pure electric resistor. All the components generated by the transformations are given in Table 1. For further details about the gyrator, we refer to literature, e.g. (Tellegen 1948; Brown, Ross, and Nichols 2001).

Table 1: Generalizing the Domain Equivalences (Brown, Ross, and Nichols 2001)

(a) From electric to magnetic

Electric domain		to	Magnetic domain	
resistance	$u = iR$	to	inductance	$\Theta = \mathscr{L}\frac{d\Phi}{dt};\ \mathscr{L} = \frac{N^2}{R}$
inductance	$u = L\frac{di}{dt}$	to	resistance	$\Theta = \mathscr{R}\Phi;\ \mathscr{R} = \frac{N^2}{L}$
capacitance	$i = C\frac{dU}{dt}$	to		$\Theta = N^2 C\frac{d^2\Phi}{dt^2}$

(b) From magnetic to electric

Magnetic domain		to	Electric domain	
resistance	$\Theta = \mathscr{R}\Phi$	to	inductance	$u = L\frac{di}{dt};\ L = \frac{N^2}{\mathscr{R}}$
inductance	$\Theta = \mathscr{L}\frac{d\Phi}{dt}$	to	resistance	$u = iR;\ R = \frac{N^2}{\mathscr{L}}$
capacitance	$\Phi = \mathscr{C}\frac{d\mathscr{V}}{dt}$	to	power source	$u = N^2\mathscr{C}\frac{d^2 i}{dt^2}$

The equations for the gyrator in differential form are as follows

$$\begin{bmatrix} \Theta \\ u \end{bmatrix} = \begin{bmatrix} N & 0 \\ 0 & N\frac{\partial}{\partial t} \end{bmatrix} \begin{bmatrix} i \\ \phi \end{bmatrix}. \qquad (16)$$

In some circuit simulators there may be problems with the differentiator and therefore one has to apply a modified formulation. One simple possibility is to use an inductivity as a substitute for the differentiator. A more sophisticated and stable method is to use the gyrator with its integral form. This can be achieved by applying Faraday's law in integral form

$$\phi = \frac{1}{N}\int u_i\, dt. \qquad (17)$$

Therefore, the gyrator equations rewrite as

$$\begin{bmatrix} \phi \\ i \end{bmatrix} = \begin{bmatrix} \frac{1}{N}\int \ldots dt & 0 \\ 0 & \frac{1}{N} \end{bmatrix} \begin{bmatrix} u_i \\ \Theta \end{bmatrix}. \qquad (18)$$

The used simulation model of the gyrator can be seen in Fig. 8. The orange highlighted blocks are the first row of (18) and the blue highlighted blocks are the second row. The connection ports for the electric circuit are green respectively yellow for the magnetic circuit. A stabilizing resistor has to be in parallel to the controlled current source to speed up the simulation.

5.2. Linear Circuit Model

First of all, we apply our developed model to a simple inductive circuit consisting of a resistor and a ideal inductor. Figure 10 shows the simple RL network when using our approach of the electric and magnetic circuit connected by a gyrator. The number of windings N to calculate the magnetic resistance ($\mathscr{R} = N^2/L$) is set to 1 (see also Tab. 1). Both forms of the gyrator (differential

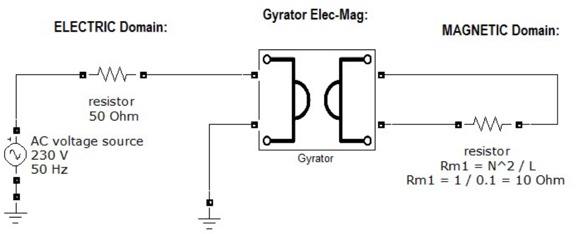

Figure 10: Simple Circuit with Gyrator.

as well as integral form) are used for the simulation to show the differences. As expected, the simulation results of the RL network with our approach and the standard one show exact the same behavior (see Fig. 11).

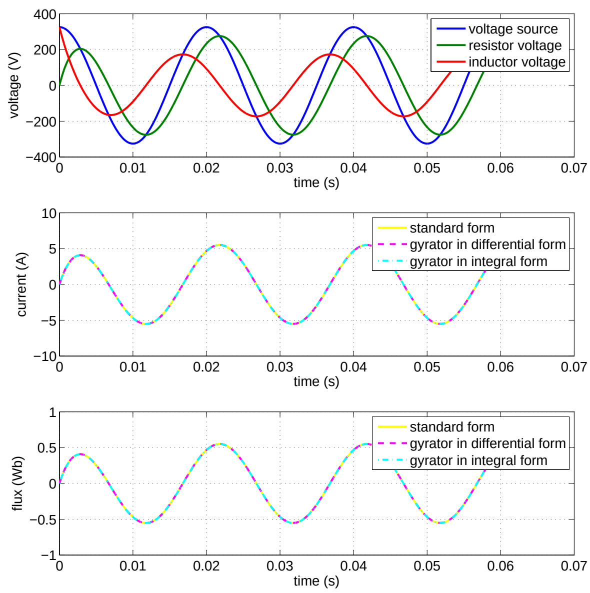

Figure 11: Simulation Results of the Simple RL Network With Gyrator.

5.3. Nonlinear Circuit Model

The linear circuit model can be seen as a linear transformer model with winding number $N = 1$. But, this model does not take the effects of saturation, hysteresis, and eddy currents into consideration. To model saturation, the linear reluctance has to be changed to a nonlinear one. The subsystem of the non-linear resistor is shown in Fig. 12.

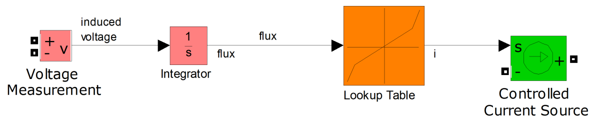

Figure 12: Model of a Nonlinear Inductance.

The current i flowing in the inductor is a nonlinear function of flux linkage ψ that, in turn, is a function of the induced voltage u_{i} appearing across its terminals, as described by Faraday's law. The voltage u_{i} is called self-induction and is given by the following relation

$$u_{\mathrm{i}} = L\frac{di}{dt} = \frac{d\psi}{dt}, \tag{19}$$

or in integral form

$$\psi = \int u_{\mathrm{i}} \cdot dt, \tag{20}$$

which results in

$$i = \frac{\psi}{L(\psi)}. \tag{21}$$

The model for the nonlinear inductance can therefore be implemented as a controlled current source, where current i is a nonlinear function of voltage u_{i} which will be computed with a look-up-table, as can be seen in Fig. 12. The red part in this figure describes (20), the look-up-table (orange) describes the flux-current characteristic and the controlled current source (green) converts the Simulink signal back to a SimPowerSystem signal.

5.4. Circuit Model with Hysteresis

The final step is to take the hysteresis behavior into account, which we do by the classical Preisach operator as it is described in chapter 3. Instead of the look-up-table, an interpreted MATLAB function block is used to describe the $i - \phi$ characteristics. The Preisach model works only between $+1$ and -1 and therefore the input and output values are scaled by their saturation values (i_{sat} & ϕ_{sat}). If the input signal raises beyond the saturation values, where the Preisach model can't work any longer, the simulation switch to the non-linear function

$$\phi(i) = c_1 ln(c_2 i). \tag{22}$$

If the input signal falls bellow the saturation values, the simulation returns to the Preisach function. This detection of the input signal is included in the code inside the interpreted MATLAB function block. Another important block is the initial condition block (IC-block - red

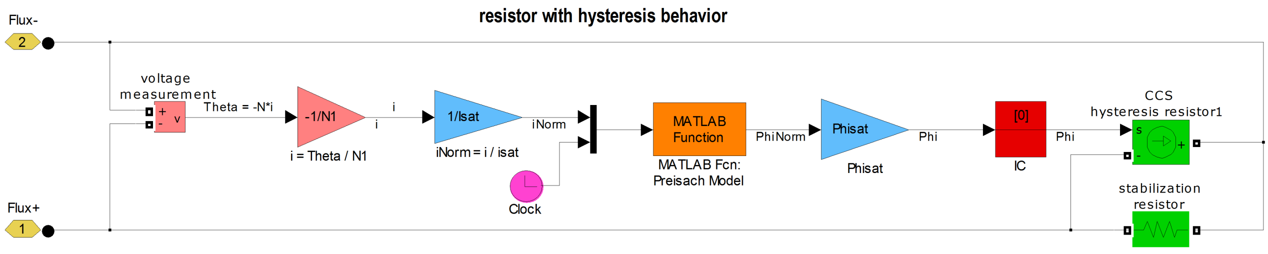

Figure 13: Resistor With Hysteresis Behavior.

block) to prevent algebraic loops in Simulink. This block provides an initial guess for the algebraic state variables in a loop.

Using a variable time stepping solver, another problem occur when using an interpreted MATLAB function block. The variable-step solvers dynamically increases or reduces the step size during the simulation by using its local error control to achieve the tolerances (Matlab 2001). Therefore all the parameters have to be stored with the correct time stamp which will be delivered by the clock (magenta).

Furthermore, the eddy currents are modeled by an additional magnetic inductance in series to the magnetic reluctance, where the inductance is calculated by $\mathscr{L} = N^2/R$ (see Tab. 1).

5.5. Three Phase Transformer

The single phase network can be easily extended now to a three phase network. There exist three different fluxes with different phase angles in this network. Therefore the three resistances with hysteresis behavior have their own Preisach function. Also included is the reluctance of the air path which is considered as constant. More details about modeling three phase transformers can be found in (Adly, Hanafy, and Abu-Shady 2003).

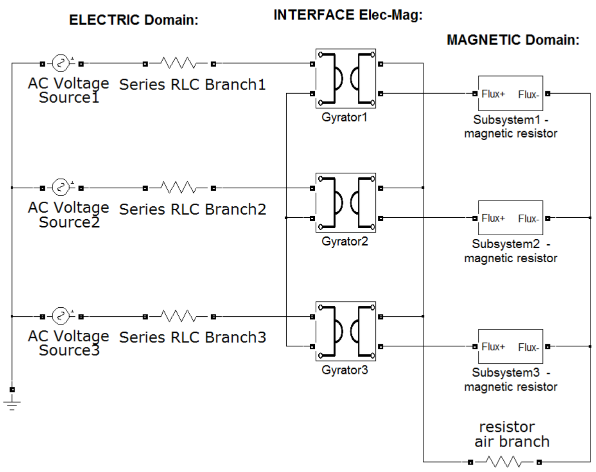

Figure 14: Three Phase Transformer.

6. RESULTS

For all circuit simulations the SimPowerSystems-Toolbox in MATLAB/Simulink® is used. The measured data for comparison with simulations are provided by a single phase transformer and a three phase transformer.

Two different simulations have been performed for comparison with the single phase transformer. The first one used the Preisach operator, where the identification procedure was based on 50Hz measurements, so that the eddy current losses are already included in the hysteresis curve. The second one used an identification procedure based on 10Hz measurements and an additional inductance in the magnetic circuit to model the eddy current losses. The results can be seen in Fig. 15. The simulation results show acceptable agreement in comparison with measurements (red line). The simulation without additional inductance (blue line) show greater deviation in the real part as the simulation with inductance (green line).

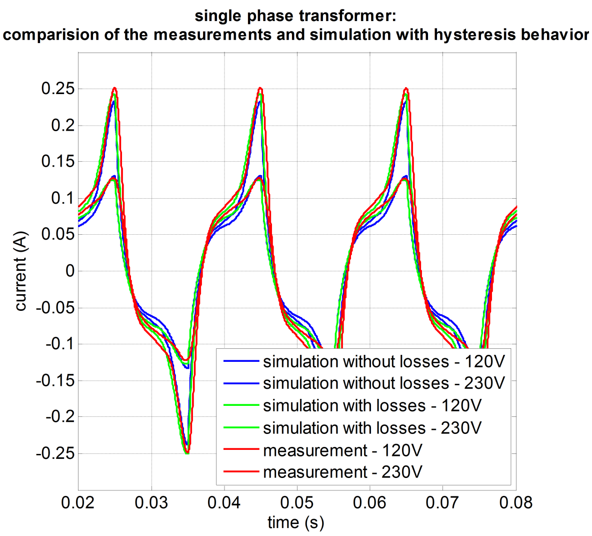

Figure 15: Results of the Single Phase Transformer.

The simulation model was extended to simulate three phase transformers as well. The results of the currents can be seen in Fig. 16. Here, the simulation results show quite good agreement in comparison with the measurements. Only the second phase has a larger deviation. It can be clearly seen that the three phases are influencing each other and therefore the signal isn't sinusoidal any more. From the results it can be seen that our model may be used to design and optimize single- and three phase transformers used in electric power systems.

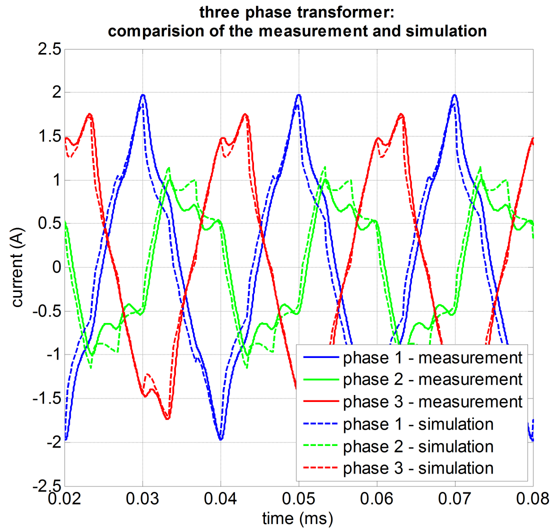

Figure 16: Results of the Three Phase Transformer.

6.1. Inrush Current

The inrush current waveforms are recorded by using an unloaded and demagnetized, single-phase transformer. Eddy currents are not taken into account. The switch-on angle for the transformer primary voltage is $\alpha = 0$.

A result for the inrush current is shown in Fig. 17, where the four first cycles of the simulated and the measured values are shown. By comparison of the measured and simulated values the agreement is very good.

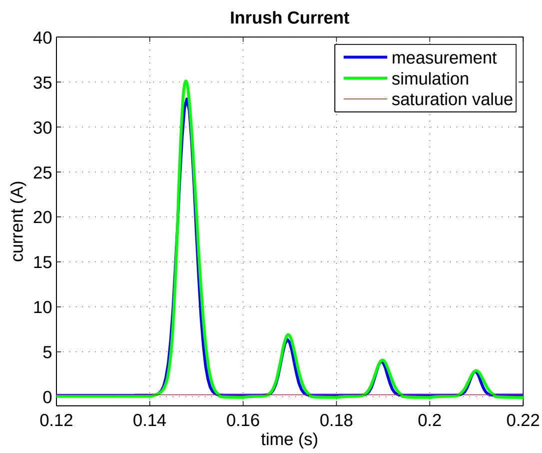

Figure 17: Results of the Inrush Current.

7. CONCLUSION

This paper demonstrated a simulation technique that allow mixed magnetic and electric systems to be analyzed in the time domain which is very useful for modeling single as well as three phase transformers. The Preisach operator has been successfully incorporated into a transformer model with the help of a gyrator. For the validation of the model, simulation results of a single phase and a three phase transformer are compared to measuremets. The simulations are in quite good agreement to the measurements.

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POLICY EVOLUTION FOR LARGE SCALE ELECTRIC VEHICLE CHARGING CONTROL

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ABSTRACT
In future smart electric grids, the control of electric vehicles' charging processes will be a central aim of demand side management. While this control enables the avoidance of possible critical peak-load values, the optimal coordination with supply from fluctuating renewables offers promising possibilities for power grid operation. Within this work, an optimization approach will be proposed that uses evolutionary optimization for computing performant control-policies for all EVs within a complex system. These policies are able to satisfy the EV users' energy demand on the one hand, while guaranteeing secure operation of the power grid on the other hand. Considering a high amount of EVs allows further the optimal integration of e-mobility into large-scale distribution networks.

Keywords: Electric Vehicle Charging Control, Probabilistic Power Flow, Evolutionary Optimization, Simulation Optimization

1. INTRODUCTION

Optimal integration of electric vehicles (EVs) into modern power grids plays an essential role in future power system operation and control. Numerous investigations have been performed in order to identify optimal charging policies for meeting objectives like peak-shaving, optimization of power quality metrics or maximal usage of power from renewable sources. Especially this interaction of zero-emission supply plants and electrified vehicles is seen as central concern, since the usage of energy from renewables directly influences the reachable environmental benefit of electric vehicles. Here, both the supply as well as the demand side show nondeterministic behavior which has to be tackled in some way. Therefore, a simulation-based optimization approach will be demonstrated, that uses metaheuristic algorithms for finding optimal charging schedules of an electric car fleet within a given system. This approach is capable of considering both, the physical power grid as well as the individual electrified traffic through probabilistic simulation models, where all nondeterministic influences can be incorporated dynamically into the heuristic search process. Each solution candidate will be evaluated a sufficient number of times through simulation in order to increase the accuracy of the performance estimation within an uncertain environment.

2. OPTIMAL CHARGING CONTROL

Various researchers examine the problem of integrating electric vehicles optimally into power grids, where direct control of charging power is seen as advantageous for reaching optimal load characteristics (Clement, 2008; Clement, 2009; Sortomme, 2011). Central challenge beside the formulation and computation of the optimization problem itself is the consideration of the individual behavior that mainly characterizes electric vehicle charging load. Different approaches try to tackle this task using static load profiles (Clement, 2008), representations of behavior using Queuing Theory (Vlachogiannis, 2009) or simulation via Monte Carlo methods (Sortomme, 2011).

All these approaches generally have in common that they try to compute static load profiles that are later used within certain optimization methods. Thus, there is no interrelated process that incorporates probabilistic behavior during the search for optimal solutions. Especially when talking about optimization in uncertain systems, simulation-based optimization with heuristic algorithms has been applied to various fields of applications and will be the central approach within this work. Here, with probabilistic simulation models, the uncertain system can be modeled holistically consisting of traffic simulation, probabilistic models of renewable supply as well as the power grid simulation model for the computation of resulting load flows.

3. SIMULATION-BASED POLICY EVOLUTION

The complete system architecture is shown in Figure 1:

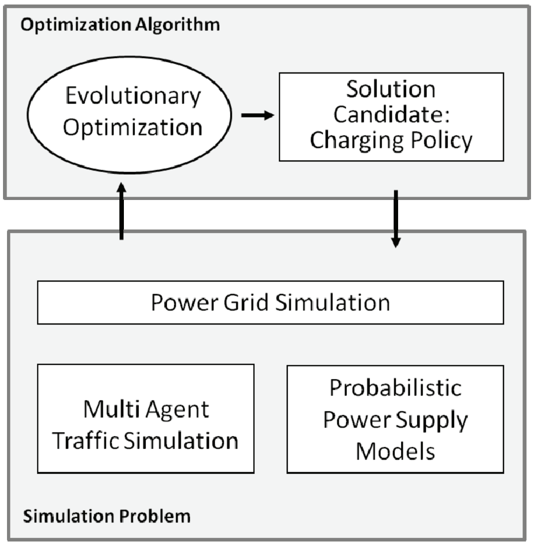

Figure 1: Simulation Optimization

Here, the problem represented by simulation consists of the distribution grid load flow simulation itself, probabilistic models for fluctuating supply from renewable plants as well as the simulation of the EV fleet. The solution candidate represented by a charging policy for all EVs is passed to the simulation for evaluation, returning its resulting fitness value to the optimization algorithm.

In the end, the finally best found charging policy should satisfy end-users energy demand while considering probabilistic driving behavior of EVs (traffic simulation), guaranteeing secure distribution grid operation (power grid simulation) as well as maximizing usage of power from fluctuating renewables (probabilistic power supply models).

3.1. Policy Optimization

In existing research literature on integrating EV fleets into distribution grids, the common approach is to implement an optimization procedure that computes optimal charging schedules based on existing knowledge and forecasted system behavior in advance. But in an uncertain and volatile system such as the underlying one consisting of probabilistically behaving agents and intermittent power supply from renewable plants, it would be more appropriate to make charging decisions on the fly, reacting to dynamic situations quickly and in a flexible manner.

Therefore, a policy-based approach is the central aim of this work. Here, each agent (EV) receives a flexible policy rather than a static schedule that makes it react to its environment dynamically during operation, but in a globally optimal manner when deciding about the agent's charging. This policy is principally the same for all agents, but using individual data from agent's environment, it leads to agent-specific charging behavior.

The basic concept is indicated in Figure 2, where the policy evaluation is indicated for a given EV that arrives at an arbitrary location which is equipped with charging infrastructure.

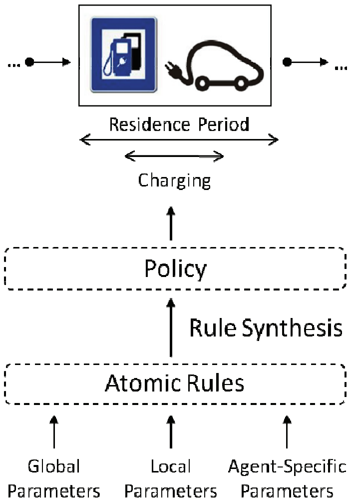

Figure 2: Policy Control

Principally, the optimized policy which finally decides the EV's charging power at a given time step is synthesized from atomic rules that consider agent-specific parameters from its environment. Out of these parameters, atomic rules are used to compute information out of them for evaluating EVs power demand as well as the state of its environment. Here, three different parameter classes can be distinguished from each other:

- Agent-specific parameters concern the EV's driving behavior, like its residence time at the actual charging station or its likelihood of getting parked at another charging spot later on.
- Local parameters consider other EVs immediately affecting the local situation in the power grid. For example, if the power grid is stressed locally because of a high amount of EVs charging at the same bus, their charging power has to be reduced in the next time step in order to avoid critical power flow conditions.
- Global parameters consider information describing the whole system's state, like the total load to the distribution grid, totally expected supply from renewables or financial aspects considering costs of electrical power supply.

Using these parameters as input for the atomic rules, each rule delivers a numeric result in the interval [0,1] that defines the agent's priority for charging. 0 would indicate that the corresponding EV should not charge at the actual time step, 1 advises it to charge with maximum power. Since a variety of criteria has to be taken into account for computing the optimal charging power of an EV, as can be estimated from the parameter classes defined above, multiple rules have to be defined that finally have to be merged in some way. Table 1 gives an overview of all defined atomic rules.

Tabelle 1: Atomic Rules

Rule	Acronym
Total Residence Time so Far	RT
Estimated Time to Departure	ETTD
Passed Residence Time at Location	PRT
Actual Irradiance	AI
Past Irradiance During PRT	PI
Estimated Irradiance to ETTD	EI
Actual Wind Speed	AWS
Past Wind Speed During PRT	PWS
Estimated Wind Speed to ETTD	EWS
Actual Base Load	ABL
Past Base Load During PRT	PBL
Estimated Base Load to ETTD	EBL
Actual Price	AP
Past Price During PRT	PP
Estimated Price to ETTD	EP
Distance to Peak Load	DTB
Mean MVA Rating	MMVA
Number of EVs Same Location	NREVL
Mean number EVs Same Location During PRT	MNREVL
Number of EVs Charging Globally	NREVC
Number of EVs charging, Same Location	NREVCL
Mean Charging Rate per EV Globally	MCR
Mean Charging Rate, Same Location	MCRL
Agent's Already Charged Energy	ACE

More detailed information about the atomic rules can be obtained from (Hutterer, 2012). Summing up, all these rules combined are capable of considering not only the single EV's needs, but also describe the global system's state concerning power grid operation and behavior of the total EV fleet. These rules now have to be combined in an appropriate way in order to compute the final charging power of an affected EV.

3.2. Rule Synthesis

Within this work, two approaches will be compared for constructing the final policy out of atomic rules. The aim of this so called "rule synthesis" is to compute a final value that describes the charging decision out of the set of atomic rules that are needed in order to consider all needed information from the agent's environment.

3.2.1. Synthesis with Linear Combination

The first approach uses a fixed mathematical structure given in Equation 1. Here, the agent's charging rate (CR) at time step *i* is computed using a linear combination of all rules *r*, each rule multiplied by a specific weight *w*, divided by the amount of rules *j*. This kind of rule synthesis is a common approach from production logistics as used in (Vonolfen, 2011) and (Beham, 2009). Here, the control variables that are manipulated during the heuristic search process are the weights w_j that describe the impact of each rule. For this kind of real-valued optimization, evolution strategies according to (Beyer, 2002) are applied.

$$CR_i = \frac{\sum_{j=1}^{J} r_{j,i} * w_j}{j} \quad (1)$$

Even if the rule synthesis using a linear combination is quite intuitive and leads to competitive results, it seems to be inflexible, disregarding the possibility of identifying potential nonlinear relationships between atomic rules. Therefore, a second approach is introduced that allows a more flexible, nonlinear combination of atomic rules, namely genetic programming (GP) (Affenzeller, 2009).

3.2.2. Synthesis with Genetic Programming

Extending the principle concept of genetic algorithms, GP uses evolutionary-inspired concepts for the heuristic search process, but is able to evolve computer programs. Within the herein described work, these computer programs take the appearance of structured trees, where leafs represent rules as defined before, that are combined by arbitrary mathematical operators which are incorporated by inner nodes. This kind of solution representation allows arbitrary mathematical combinations of atomic rules.

To give some overview on GP, finding first research activities in the 1980s, the computationally expensive concept of GP was pushed majorly by the steady increase of computational power in the last two decades. One of the most important publications in this field was (Koza, 1992), stating GP as automated invention machine for numerous practical applications like the artificial ant problem or later applications of symbolic regression (Affenzeller, 2009), to name the most popular ones, while (Langdon 2002) finally provides profound analysis in the context of GA schema analysis. This ability of GP to automatically construct new solutions (programs) to a given problem is enabled by its special kind of solution representation, that is not restricted to a fixed structure (like fixed-length one-dimensional array as in standard GA), but forms a hierarchical computer program of variable length, consisting of functions and terminals. In the herein presented application, functions are inner nodes of the structured tree, while terminals can be constants or atomic rules. Figure 3 gives an exemplary tree that could represent a policy for the addressed problem.

Here, inner nodes that represent functions are indicated in dotted style, while terminal nodes are plotted in solid style. In this case, the policy would consider the estimated time to departure of the appropriate EV, the actual irradiance and thus the supply from photovoltaics, as well as the mean charging rate of all other EVs in order to not stress the distribution grid with peak charging load. Out of this mathematical combination, finally a numerical value is derived that represents a charging decision.

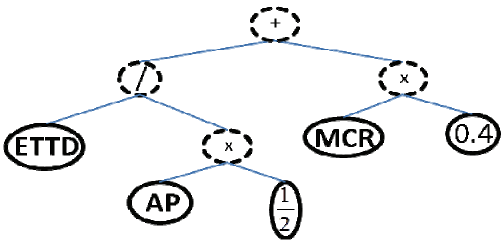

Figure 3: Exemplary GP Solution

The great advantage of this kind of flexible solution representation compared to the application of a fixed-structure linear combination is that GP is able to find nonlinear coherences between atomic rules with variable length. Using any arbitrary combination of mathematical operators as inner nodes, the degree of freedom for finding performant policies gets increased drastically. Further, since GP is not constrained to use the hole set of atomic rules for solution creation, simpler policies can be found too. In the end, its disadvantage is that the possible solution space is increased drastically.

For overcoming this problem and pruning the solution space, the possible grammar is restricted to the following operators in Table 2. The grammar in this case defines the set of functions (inner nodes) that is applied for evolving solution candidates during the genetic search process. Further information on usable grammar can be obtained in the appropriate literature (Affenzeller, 2009) as well as in HeuristicLab (www.heuristiclab.com) which is used as heuristic optimization framework.

Table 2: GP Grammar

Arithmetic Operators	{+, -, x, /}
Conditional Operators	Conditions {IfThenElse}
	Comparisons {<,>}

3.3. Policy Evaluation

The principal process of the policy evaluation can be obtained from Figure 4: in each time step of the simulation, if the agent remains at a charging station, the policy evaluation is initiated in order to compute the resulting charging power. After gathering all the information the agent needs (global, local as well as agent-specific parameters), the respective outcome of the atomic rules is computed. Combining these results according to the rule synthesis method, the final charging power can be derived. The atomic rules are generally constructed such that each rule as well as its respective weight results in a numeric value in the interval [0,1]. Thus, for the linear combination, the final results exists in the interval [0,1] as well. This value therefore is interpreted as charging rate and is multiplied by the maximum possible charging power per EV. Thus, when using rule synthesis with linear combination, no invalid charging power can occur from the policy, as long as the decision variables are kept within [0,1].

When using rule synthesis with GP, the policy directly outputs the desired charging power. Here, possibly invalid values may result from the solution candidate (negative charging power, too high charging power) because of the high degree of freedom when building the structured tree, which has to be managed in some way. A reason could be for example the addition of a constant or a multiplication of rules with some value. In this work, this is considered the following way: if the resulting value is less than 0 or greater than the maximum charging power, the value is set to 0 or the maximum value respectively and a penalty is added to the fitness term according to the degree of the violation. Since power-flow simulation may not converge in exceptional conditions (for example if the resulting charging load takes unmanageable values), this penalty is turned into a so called “death penalty” for the respective solution. Thus, if a solution candidate leads to non-convergence of the load-flow simulation, it is assumed to be useless.

3.4. Solution Evaluation

The evaluation procedure of a solution candidate is indicated in Figure 4.

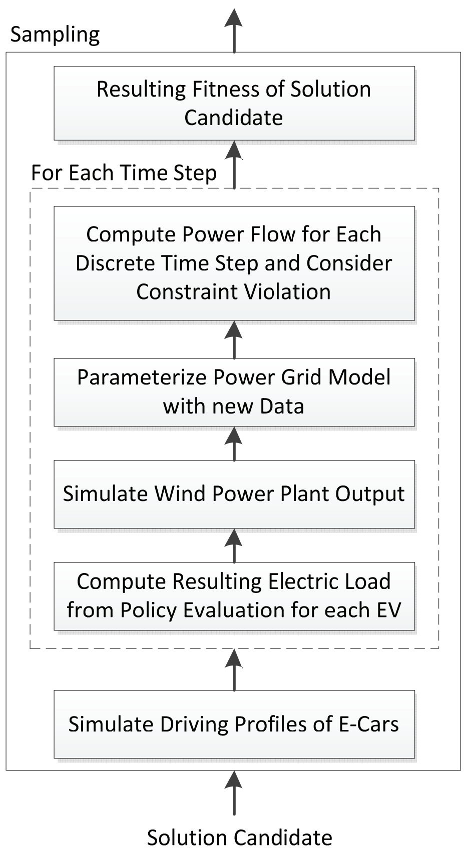

Figure 4: Solution Evaluation

When evaluating a solution candidate in simulation, first of all the traffic simulation is performed over the whole time interval, in order to describe the expected EV behavior. Having this behavior in form of computed driving profiles for each agent, its resulting charging power is computed for each time step that follows from the evaluation of the respective policy. With the charging load caused by all agents, further the power flow simulation is executed for each time step considering probabilistic injection from renewable sources, in order to compute the actually occurring load flow in the physical distribution grid. With the final power flow solution, all constraints as well as the objective function can be evaluated in order to derive the fitness of the solution.

3.5. Evaluation under Uncertainty

When evaluating a solution candidate in an uncertain environment, estimating its real performance is a ubiquitous as well as challenging task which might be computationally expensive. This is due to the stochastic nature of the evaluation as well as the slow convergence of a performance measure estimator relative to the number of runs performed.

The obtained fitness from a simulation run can be formulized as

$$\tilde{f} = f + \varepsilon ,$$

where the obtained fitness value $\tilde{f}$ deviates from the real fitness caused by some probabilistic noise ε. This noise is mainly defined in literature as being normally distributed (Stagge, 1998; Fu 2002) by $\mathrm{N}(\mu,\sigma)$ with zero mean. While the evolutionary search proceeds rapidly it may happen that some other individual than the best is chosen as parent for the next generation, caused by an inaccurate estimate of f. This may lead to a decrease in progress velocity and may also lead the evolutionary search into unpromising regions of the search space. Thus, doing multiple evaluation runs and averaging over the obtained values of $\tilde{f}$ is important for estimating the candidates' real performance. Since The accuracy of this estimate cannot improve faster than $1/\sqrt{N}$, where *N* is the number of computed samples as indicated in Figure 4, choosing an appropriate value of *N* is essential when addressing computational costs of evaluation. Different approaches have been investigated both in literature as well as by the authors of this paper (Hutterer, 2012) for inferring *N* in an adaptive way during the search process. Within this paper, it is seen as sufficient to experimentally derive a performant value for *N* and fix it.

4. SETTING UP EXPERIMENTS

As highlighted in the introductory chapter, many researchers are investigating this optimal integration of EVs into distribution grids nowadays. When considering the treated power grid levels, these researchers mainly focus on quite low-level integrations in mostly radial distribution feeders or even lower. The special advantage of the herein used policy-based control approach, as discussed extensively in (Hutterer, 2012), is that it enables the consideration of huge EV fleets and thus consider their integration from a higher level point of view. Hence, in this work, larger distribution networks are considered that will be discussed as follows.

4.1. Large-Scale Distribution Grid Testcases

In order to guarantee universality for the considerations within this work, the well known IEEE distribution grid testcases[1] will be used and modified for representing valid test instances. Throughout the grid, a huge EV fleet is modeled, where each single agent can produce a charging load of maximum 11kW, related to a three-phase charging process with 400V and 16A, as exemplarily possible when using a Mennekes VDE (Type 2) plug connector. This configuration, as existing for example when charging the well known Tesla Roadstar, is certainly one of the most important technical specifications in this field in actual developments and is seen to get a common standard throughout EV-manufacturers.

The power grid simulation model is being downscaled such that the cumulated charging power of all agents sums up to 20% of the daily peak load maximally in each considered case. For representing individual electrified traffic from a power grid point of view, the relevant behavior that has to be modeled describes time interval and location of each EV when being parked to a charging station and thus being ready for charging. Based on real-world traffic data from an Austrian survey[2], two most relevant driving patterns can be extracted for a week day, namely the pattern of full-time and half-time workers. Within each pattern, three different locations are modeled for parking at home, at work and at any location in free time (shopping, education, entertainment). For each location, different probabilities for the existence of a charging infrastructure are modeled, describing a possible future infrastructure scenario from an actual point of view: at home, each EV user has an own charging station. At work, there is a probability of 50% that an appropriate infrastructure is available. For locations where potential users remain in free time, this probability is assumed to be 25%.

The resulting charging load at a specific location is than being correlated to a corresponding bus within the distribution grid model. Within each simulation run, synthetic driving profiles are computed from prototype-

[1] Testcases provided by University of Washington, UW Electrical Engineering. (1999). http://www.ee.washington.edu/research/pstca/

[2] Federal Ministry for Transport, Innovation and Technology, Verkehr in Zahlen 2007, http://www.bmvit.gv.at/verkehr/gesamtverkehr/statistik/downloads/viz07gesamt.pdf, Retrieved 09.07.2012

profiles, being randomized in terms of driving time and residence time at specific locations. Thus, the probabilistic behavior of individual traffic can be modeled based on real-world data and incorporated into the evolutionary optimization process enabled by the simulation-based approach.

For modeling the power output of renewable sources, wind power plants as well as large-scale photovoltaic plants are added to the distribution network. For wind power modeling, the corresponding wind speed values at the plant sites are sampled from a Weibull-distribution as described in (Vlachogiannis, 2011), where their power curves are assumed such that each plant reaches its maximum output at cut-off windspeed. Using the sampled wind speed value, with the plant's power curve the resulting power output of the plant can be modeled.

Photovoltaic-plants follow a typical daily generation profile that is randomized in each time step with a standard deviation of 10%, considering a typical uncertainty in photovoltaic-generation forecasting. All renewable supply models are designed such that they cumulated produce in average 50% of the energy needed for all EVs in the system.

In order to consider realistic power grid conditions, the base load is modeled as described in the IEEE testcases, but randomized too for simulating a probabilistic demand side with a standard deviation of 4%.

A thorough discussion of the used modeling approach can be obtained from (Hutterer, 2012). The configurations for both test cases are shown in Tabelle 13, where the distribution of renewable plants throughout the grid model as well as the EV fleet are defined.

Table 3: Test Cases Configurations

14-Bus Testcase	
# EVs	960
# Photovoltaic Plants	3
# Wind Plants	2
Bus # with Photovoltaic Injection	6,8,10
Bus # with Wind Power Injection	3,12
Bus # with fixed Generation	2
Slack Bus #	1
118-Bus Testcase	
# EVs	4366
# Photovoltaic Plants	9
# Wind Plants	3
Bus # with Photovoltaic Injection	12,31,46,54,59,61,87,103,111
Bus # with Wind Power Injection	25,49,100
Bus # with fixed Generation	10,26,65,66,69,80,89
Slack Bus #	1

5. PROBLEM FORMULATION

A formal description of the optimization problem shall now be stated in order to underline the application: given a fleet of EVs within a distribution grid, a vector $Pc = [Pc_{1,1},...,Pc_{i,n}]$ describes the active charging power of each EV n at time step i over a given time interval. At the end of this considered planning frame, each EV must have received a specific amount of energy for satisfying its daily demand: $E_{\min,n} \le \sum_{i=1}^{I} Pc_{i,n} * \Delta t_i$

This constraint is valid assuming that batteries are big enough and the one-way distance of an EV does not lead to a low state of charge. Since additional load caused by related charging of electric vehicles can endanger power grid security, constraints have to be satisfied that ensure secure distribution grid operation. Thus, within each time step i, power flow constraints have to be considered. Steady-state security constraints can be formulated (Wood, 1996) for ensuring lower and upper bounds for generator real and reactive power output Pg and Qg,

$$Pg_{j,\min} \le Pg_j \le Pg_{j,\max}$$

$$Qg_{j,\min} \le Qg_j \le Qg_{j,\max} ,$$

maximal power flows over transmission lines Pf,

$$Pf_k \le Pf_{k,\max} ,$$

as well as admissible voltage deviations ΔV ,

$$\Delta V_{k,\min} \le \Delta V_k \le \Delta V_{k,\max} ,$$

for all buses $j=1...J$ and all transmission lines $k=1...K$.

While satisfying all formulated constraints, the objective function shall be defined of minimizing financial costs of power supply.

Since charging power is restricted to a maximum value, an additional constraint has to be formulated when using the GP-based policy synthesis as discussed in section 3.2, being formulized as:

$$Pc_{i,n} \le P_{c,\max} .$$

What is important to mention at this point is that the vector Pc as introduced above containing the charging power of each EV at each time step is never present in a static manner. Each value $Pc_{i,n}$ results from a single evaluation of the policy within the simulation of a certain time step. Therefore, as indicated in Figure 4, the load flow in the system is computed within each time step in order to check the constraints. The finally obtained fitness function is stated in Equation 2, where $\overline{CV(Pc)_i}$ is a vector containing the quadratic violations of each constraint, multiplied by $\bar{k}$ being a vector with fixed weights of the constraint violation value relative to the financial cost function value.

$$\sum_{i=1}^{24} [Cf(Pc)_i + \bar{k} * \overline{CV(Pc)_i}] \quad (2)$$

Since the objective concerns financial costs of energy supply for charging electric vehicles, a daily price profile is assumed that is taken from the European energy exchange as used in (Hutterer, 2012).

6. EXPERIMENTAL RESULTS

For the experiments performed within this work, evolutionary algorithms are used, depending on the applied policy synthesis approach. For optimizing the weights for the fixed-structure linear combination, Evolution Strategies (ES) are applied according to (Beyer, 2002). ES are generally performant metaheuristics for real-valued optimization problems and proven to be suitable for simulation-based optimization (Hutterer, 2012). For the GP-based evolution of policies, Genetic Algorithms (GA) are applied. Both classes of algorithms are executed in HeuristicLab based on their standard implementations. The finally used configurations can be obtained from Table 4 and Table 5.

Table 4: Algorithm Configurations 14-Bus Testcase

Type	(5+15)-ES
Manipulator	SelfAdaptiveNormalAllPositions-Manipulator
Recombinator	Average Crossover
Parents per Child	2
Stopping Criterium	5000 Generations
Sampling	Sample Each Solution 3 Times
Type	GA
Manipulator	MultiSymbolicExpressionTree-Manipulator
Recombinator	SubtreeCrossover
Population Size	250
Mutation Probability	15%
Stopping Criterium	200 Generations
Sampling	Sample Each Solution 3 Times

Table 5: Algorithm Configuration 118-Bus Testcase

Type	(5+10)-ES
Manipulator	SelfAdaptiveNormalAllPositions-Manipulator
Recombinator	Average Crossover
Parents per Child	2
Stopping Criterium	5000 Generations
Sampling	Sample Each Solution 6 Times
Type	GA
Manipulator	MultiSymbolicExpressionTree-Manipulator
Recombinator	SubtreeCrossover
Population Size	150
Mutation Probability	15%
Stopping Criterium	200 Generations
Sampling	Sample Each Solution 6 Times

Further details on the used configurations can be obtained from HeuristicLab and from the appropriate literature respectively (Affenzeller, 2009).

6.1. Results for the 14 Bus Testcase

The obtained best solution is shown in Table 6, showing the obtained weights for the given atomic rules. It can easily be seen, that most rules are weighted near to 1, in order to construct the final policy out of them.

The finally best found solution for the GP-based rule synthesis cannot be visualized at this point, since it forms a structured tree of length 28 (number of used nodes) and depth 5. Some statements can even be done: the best found tree uses only 9 out of the 24 atomic rules for synthesizing the policy. This means that the rules are highly correlated to each other (which is obvious) and not all of them are needed for finding valid policies. Table 7 shows same numeric results.

Table 6: Best Solution 14 Bus Testcase

Rule	Weight	Rule	Weight
RT	1	AP	0.9166
ETTD	1	PP	0.6943
PRT	1	EP	0.9166
AI	0.9613	DTB	0.9572
PI	0.9959	MMVA	0.8560
EI	0.2370	NREVL	0.6080
AWS	0.9814	MNREVL	0.9393
PWS	1	NREVC	0.8132
EWS	0.5910	NREVCL	1
ABL	1	MCR	0.9939
PBL	0.9861	MCRL	0.9548
EBL	1	ACE	0.6544

Table 7: Numeric Results 14 Bus Testcase

Fitness	Standard Deviation of Fitness: 100 Replications
Synthesis with Linear Combination	
476.20	1.04%
GP-based Synthesis	
512.01	3.1%

The fitness addresses the resulting costs (in Euro) for supplying energy for charging the EV fleet. These costs only address the energy-generation costs, which vary in a range of around 0.03 to 0.08 per kWh over a typical day at the European energy exchange (EEX). The price that a consumer would have to pay additionally contains taxes as well as a fee to the power grid operator. Each solution is evaluated over 100 simulation runs for final results in order to obtain its robustness within the uncertain environment. Therefore, the standard deviation of the obtained fitness over these 100 runs is used as robustness estimator.

As can be seen in Table 7, the synthesis with fixed structure linear combination outperforms GP-based synthesis in both metrics. Thus, the harder heuristic search caused by an increased solution space when trying to find a valid solution with GP dominates its advantage of finding nonlinear coherences between rules.

Nevertheless, both approaches are capable of finding feasible (all constraints are satisfied) solutions with optimized financial costs of energy supply.

6.2. Results for the 118 Bus Testcase

As can be seen from the algorithm configurations, for the second testcase, quite lower population sizes have been used. This is due to the fact that this testcase considers 4366 EVs and therefore the evaluation of the policy when simulating its performance has to be executed more than 4 times more often than in the smaller testcase. Thus, population size has been decreased in order to keep the optimization computationally tractable.

Table 8: Best Solution 118 Bus Testcase

Rule	Weight	Rule	Weight
RT	1.0000	AP	0
ETTD	0.2406	PP	0.0812
PRT	1.0000	EP	0.6627
AI	0.3997	DTB	0.2803
PI	1.0000	MMVA	1.0000
EI	1.0000	NREVL	0.3945
AWS	1.0000	MNREVL	1.0000
PWS	0.3103	NREVC	0.0654
EWS	0.6412	NREVCL	1.0000
ABL	0.2891	MCR	0.9603
PBL	0.4047	MCRL	0.4853
EBL	1.0000	ACE	0.8274

Table 9: Numeric Results 14 Bus Testcase

Fitness	Standard Deviation of Fitness: 100 Replications
Synthesis with Linear Combination	
2556.13	6.0%
GP-based Synthesis	
2612.20	6.8%

The best found solution as visualized in Table 8 differs with respect to the smaller testcase drastically, considering a much higher variation in the single weights. Taking a look at the numerical comparisons in Table 9, once more the given fixed structure synthesis outperforms the GP-based one. Comparing the reached fitness-values of both testcases, in the 14-bus case costs of 0.4958 result per single EV, while these costs are increased to 0.5854 in the 118-bus case for the best solution. Since in both cases same generation costs are assumed for the power grid simulation, it can be stated that the solution of the smaller testcase has better overall quality, proving that the optimization task in the second case seems to be harder.

CONCLUSION

In this work, a simulation optimization framework has been proposed that is capable of computing optimal charging decisions for a huge fleet of electric vehicles for optimally integrating them into distribution grids.

These decisions are principally performed using flexible policies that enable the EVs to act individually within a dynamic environment. The respective policies are evolved using evolutionary computation techniques, where the search space is spanned through a simulation ensemble consisting of the electric power grid model, electric vehicle behavior models as well as probabilistic supply models. Two different representations have been formulated and compared to each other that enable the synthesis of the final policy using a set of atomic rules. Since these variants for rule synthesis majorly influence the evolutionary search, comparisons have finally been performed for evaluating reachable solution quality based on two practical test instances.

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IDENTIFYING OPPORTUNITIES OF CO-LOADING BY MEANS OF SIMULATION

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ABSTRACT

This paper discusses bundling of freight activities at the operational level. Shippers attain scale economies and a better utilization of transport equipment through consolidation of freight inside a loading unit. This may on the one hand reduce the costs of pre- and end-haulage by road or on the other hand increase the attractiveness of intermodal freight transport for further continental distribution. A discrete event simulation model is developed to investigate possible benefits of consolidation in a real-life situation in which three shippers each operate a distribution centre (DC) in the neighbourhood of an intermodal terminal in Western Europe. The organization of a crossdock to consolidate freight of multiple shippers may lead to a reduction in throughput time of loading units. Second, simulation results show that capacity gains can be realized through a shift to non peak periods. The third performance measure to evaluate the consolidation scenario is the fill rate of loading units. The consolidation scenario leads to an increase in the average fill rate over all load orders in all three DC's. Finally, the consolidation scenario leads to a reduction in number of loading units necessary over the observed period.

Keywords: horizontal collaboration, shipper consolidation, discrete event simulation

1. INTRODUCTION

In this paper a simulation study is described in which potential benefits of horizontal cooperation between shippers are identified. The cost of freight transport may be decreased by raising the fill rate of loading units. Shippers attain scale economies and a better utilization of transport equipment through consolidation of freight inside a loading unit. This may reduce costs of pre- and end-haulage by road and increase the attractiveness of intermodal freight transport for further continental distribution. Co-loading of freight reduces the amount of trucks on the road. Societal gains are achieved by decreasing the amount of air pollution, transport noise, accidents and congestion.

According to Van der Horst and De Langen (2008), coordination in hinterland transport chains is required to make hinterland transport chains efficient and effective. The authors identify coordination problems and evaluate mechanisms to enhance coordination in hinterland freight transport. Ergun et al. (2007) study shipper consolidation in the context of collaborative logistics in the trucking industry. Their goal is to identify sets of lanes of multiple shippers that can be submitted to a carrier as a bundle rather than individually, in the hope that this results in more favorable rates. The authors focus on the simplest variant, which is static and involves only full truckloads. The problem is formulated as a lane covering problem and heuristic solutions are proposed. Consolidation of freight is often proposed to reduce truck traffic in urban areas. Kawamura and Lu (2007) compare logistics costs with and without delivery consolidation in urban centers, under different sets of conditions that include population density, area size and truck weight regulation. Factory gate pricing (FGP) is an alternative approach to transport consolidation, as proposed by le Blanc et al. (2006). Under FGP, products are no longer delivered at the retailer distribution center, but collected by the retailer at the factory gates of the suppliers. The authors study asymmetric distribution networks in which supplier sites greatly outnumber retailer distribution centers. A case study is performed of a Dutch retail chain of slow moving dry grocery goods. This setting differs from the type of distribution network studied in this paper.

We study a real-life situation in which three shippers each operate a distribution centre (DC) in the neighbourhood of an intermodal terminal in Western Europe. The intermodal terminal is situated in the hinterland of a major port, offering rail, barge and road connections to the port area. Inbound flows arrive at the DCs through the intermodal terminal. The DCs are responsible for further continental distribution of goods. In this paper the consolidation of these outbound flows is analysed. Outbound flows are mainly transported by truck. To a limited degree freight is carried by rail or short sea shipping. Warehousing operations are centralized at the three DCs, implying lower warehousing costs, but higher transport costs. Each DC is specialized in a certain product category (in order to guarantee confidentiality, product categories are referred to as A, F or Q) and uses a separate planning system. A discrete event simulation model is built to analyze opportunities of consolidating outbound freight flows of the three DCs through a crossdock, situated at or nearby the intermodal terminal. No assumptions are made on the operational implementation of the crossdock. The crossdock is a fictitious location where the three flows of the warehouses arrive jointly, so that load orders with the same destination may be grouped in a single loading unit.

2. DISCRETE EVENT SIMULATION MODEL

A discrete event simulation methodology is described to analyze the bundling of outbound freight flows of three nearby DCs to their joint hub destinations. Long haul truck transport distances are considered for the continental distribution of freight in Europe. The model is constructed in the simulation software Arena. In section 2.1 a conceptual model is developed of current operations in the shipping area of each DC. A DC has its own warehouse and shipping department and plans the loading of its own trailers and containers. Data is registered at the DCs for a time period of ten weeks to serve as input for the simulation model (section 2.2). Assumptions underlying the simulation model and consolidation strategy are summarized in section 2.3. Section 2.4 gives an insight in the performance measures generated by the simulation model.

2.1. Conceptual model

Figure 1 depicts the current operations in the shipping area of each DC. The customers or entities in our discrete event simulation model are load orders arriving from the warehouse into the shipping department of each DC and need to be handled at one of the available gates. Load orders consist of boxes in various sizes, which may be palletized or not. In the shipping department the boxes or pallets are loaded into trailers or containers. The arrival of load orders from the warehouse serves as an input for the simulation model of the shipping department. The warehouse planning and operations are an external source of load orders and thus not incorporated in the simulation model. The arrival time depends on the warehouse planning and operations and is thus assumed to be given. Next, load orders queue for handling at the gates. DC 1 has 16 gates available, DC 2 and DC 3 each have 17 gates available. The service delivered by the resources or gates is the loading of boxes or pallets onto loading units, which may be containers or trailers.

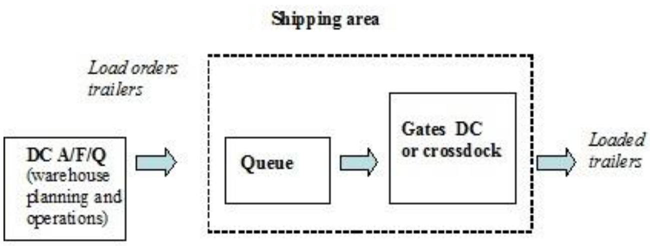

Figure 1: Conceptual model

Examples of state variables in this discrete event system are the status of the gates (idle or busy), the number of load orders waiting in a queue for handling at a gate or the time of arrival of a load order in a queue for handling at a gate. Events are the arrival of a load order in the shipping department or the completion of service of a load order at a gate.

In the simulation model of the current situation three separate queueing systems for each DC are constructed. The assignment of load orders to loading units is taken from the given planning in the available data set described in section 2.3. Containers or trailers leave the site when the last load order is put onto the loading unit at a gate in the shipping department. Between the first and last load order assigned, a loading unit is waiting at a gate or at the parking area close to the gates. In the simulation model of the future scenario the load orders of the three DCs arrive as a joint input process for a single service system representing the shipping area of the fictitious crossdock.

2.2. Data requirements

The simulation model requires data on the arrival process of load orders in the shipping department and on the service process of load orders at the gates.

A data set of load orders is tracked over a time period of ten weeks in each DC. Information is provided on the following attributes of a load order. The first attribute *'shipping time'* represents the moment at which the load order arrives in the shipping department. In the data set only the arrival times of the first and last carton are given. A random moment based on a uniform distribution between this minimum and maximum arrival time in shipping is assigned to each load order. In the data set of the current situation, each load order is destined for a certain loading unit, represented by an *identification number*. The next five attributes *(number of cartons, cubage, weight, palletized or not and number of pallets*) are necessary to determine the fill rate of containers or trailers and to consolidate load orders in the consolidation scenario. The next attribute marks whether the load order follows from either one of two special systems for warehouse operations in the distribution centres under investigation. The abbreviation '*WOW*' refers to Warehouse on Wheels. In this system load orders are loaded and stocked on site for a short time period with the objective to balance the warehouse operations. '*PH*' stands for 'pack and hold', which is a similar system but load orders are stocked internally at the shipping department of DC 1. The attribute '*DC*' indicates from which distribution centre a load order is originating. The attribute *'consolidator block*' identifies the carrier and hub for which the load order is destined. 34 possible consolidator blocks or destinations are identified. *Direct drops* are loading units which are delivered directly to the end customer. The final attribute *'cut off time'* refers to the moment at which the container or trailer must leave the site to arrive on time at destination.

The service process represents the loading of cartons or pallets onto loading units at the gates. Each load order requires that a number of cartons or a number of pallets is loaded onto a container or trailer. A probability distribution is applied to model the time necessary to load a single carton or pallet onto a loading unit. To this end a triangular distribution is chosen. The triangular distribution is identified by three parameters: mode, minimum and maximum value. The triangular distribution offers the advantage that only a fixed range of values is allowed and parameters are simply to determine. For the service time of pallets a mode of 5 minutes is experienced in practice. The minimum and maximum value are assumed to deviate 20%, leading to a minimum of 4 minutes and a maximum time to load a pallet of 6 minutes. When goods are not palletized, a service time per carton is applied. A service time of 0.45 minutes per carton is mostly observed, leading to a minimum value of 0.36 minutes and a maximum value of 0.54 minutes.

2.3. Assumptions

In the consolidation scenario the simulation model recombines load orders of various DCs in a single loading unit, based on a number of predefined rules. Load orders from the three DC's destined for the same consolidator block are bundled. Consolidator blocks represent joint hub destinations. Figure 2 depicts the restrictions imposed on the possibility to bundle freight. First, load orders for certain export destinations are not sent through the crossdock. Pack lists for these export destinations have to be generated in advance and cannot be changed. Secondly, direct drops are treated in the shipping department of the three warehouses separately and not in the crossdock. These load orders are sent directly to customer sites and therefore cannot be bundled with other load orders. Since the crossdock scenario does not yet exist, an assumption has to be made about the number of gates available in this future situation. Simulation results presented in section 3 are based on 30 gates in the crossdock and 5 gates remaining in the three separate DC's to handle load orders related to certain export destinations and direct drops. A volume of 2 m³ per pallet is assumed when combining palletized and not palletized load orders. In the new crossdock loading units are filled to their maximum volume of 60 m³. The cut off time of load orders is taken into account. Load orders are added to a loading unit when their cut off time matches the cut off time of load orders already assigned to the loading unit. Over the observed data period 34 consolidator blocks or destinations are served, of certain combinations of consolidator blocks are allowed in a single loading unit.

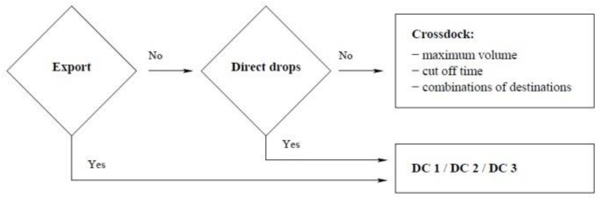

Figure 2: Consolidation through crossdock

2.4. Performance Measures

Table 1 presents the relevant outputs measured in the simulation model. The throughput time is the total time that a loading unit spends on site, including loading time and standing time. Standing time is the time period in which a loading unit is waiting at the gate or on the parking area. Load orders in the WOW or PH system are not taken into account when calculating the throughput times and standing times. These load orders are meant to wait and thus would give a misleading impression of the real throughput time and standing time. Weekends are excluded from the time performance measures, as the three DCs normally do not operate during this time. The capacity utilization of the gates is expressed as the percentage of time that the gates are in use for loading a carton or pallet onto a container or trailer. In this definition a gate is not in use when a loading unit is waiting but nothing is being loaded. The fill rate is expressed as the percentage of the maximum volume of a loading unit filled. Due to the type of products, weight is not a limiting factor. However, weight could be taken into account when consolidating load with other parties. The fill rate is measured for each DC and for palletized and non-palletized loading units separately. Load orders in the WOW and PH systems are included in the calculation of fill rates. A final output to compare the current and consolidation scenario is the number of loading units necessary for delivering all goods to their destination.

Table 1: Performance measures

Throughput time	Average Maximum
Standing time	Average Maximum
Capacity utilization gates	% time in use (avg and max)
Fill rate	% of volume per distribution centre Palletized or not
Number of loading units	

3. SIMULATION RESULTS

In this section simulation results are presented based on ten separate simulation runs, each representing a single week of operations. First, results on all performance measures listed in Table 1 are discussed. Next, in section 3.5 a statistical comparison is made between the current scenario and consolidation scenario, demonstrating significant differences in performance measures.

3.1. Throughput Time and Standing Time

The throughput time of loading units is defined as the time between the first and last order loaded onto the loading unit. When a loading unit is immediately loaded and so doesn't have to wait, this equals the sum of service times of its load orders at the gate. Table 2 summarizes the average and maximum throughput time of loading units for the current scenario and the consolidation scenario. In the consolidation scenario the throughput time for the separate DC's refers to the loading units for certain export destinations and direct drops, which are excluded from consolidation as stated in section 2.3. Results are expressed in days and weekends are not included. Nine outliers with a throughput time of at least seven days are excluded from the analysis.

Table 2: Throughput time of loading units (days)

	Current		Consolidation	
	Avg	**Max**	**Avg**	**Max**
DC 1	1.0679	4.8923	0.5751	4.8923
DC 2	1.3361	6.2023	0.8701	4.7052
DC 3	1.4471	6.1232	1.7311	4.9941
Crossdock	/	/	0.4968	4.7926

The comparison in table 2 shows a reduction in maximum throughput time of loading units of one day when consolidating freight and assuming the warehouse operations as given. The average throughput time also reduces from at least one day in the current scenario to half a day at the crossdock in the consolidation scenario. Throughput times depend on the warehouse planning and operations. Considerable time may pass between the arrival in shipping of the first and last load order destined for the same loading unit. Time lags also occur between the arrival of the first and last carton of a single load order. However, through consolidation a significant reduction in throughput time of loading units may be realized.

The standing time is equal to the throughput time of a loading unit minus the total service time of all load orders assigned to the loading unit. The same reduction in standing time is observed as discussed in the previous section on throughput time. The loading of containers or trailers only takes up a very limited amount of time. Loading units spend most part of their time waiting on site.

3.2. Capacity Utilization

The capacity utilization is the proportion of time the gates are in use during the simulation run. This only includes the time during which a container or trailer is being loaded, not the time while a loading unit is just standing at the gate. The simulation run includes nights and weekends, which are retained in the performance measures on capacity utilization. Weekends and nights account for respectively 28 % and 23.8 % of simulation time. Results of the current scenario in Table 3 show that the 17 available gates in DC 2 are at most used for 81 %. In DC 1 and DC 3 available gates are fully occupied during peak periods but on average only 20% of the available capacity are loading a container or trailer. Capacity is thus still available during other non-peak periods during the day or during night and weekend shifts. Capacity utilization in the consolidation scenario depends on the assumptions made on the number of gates. It is assumed that the crossdock disposes of 30 gates and 5 gates in each DC are available for handling certain export load orders and direct drops. The assumed capacity level is sufficient to deliver the same service level as in the current situation. Capacity gains could also be realized through a shift to non peak periods.

Table 3: Capacity utilization of gates (%)

	Current		Consolidation	
	Avg	**Max**	**Avg**	**Max**
DC 1	0.1950	1.0000	0.1400	1.0000
DC 2	0.0811	0.8235	0.0780	1.0000
DC 3	0.2013	1.0000	0.2004	1.0000
Crossdock	/	/	0.1668	1.0000

3.3. Fill Rate

Considering the type of goods, the fill rate is calculated based on volume. The maximum volume for loading units is set equal to 60 m³. In Table 4 and Table 5 the average fill rates in the three DC's are given for the current and future scenario. A further distinction is made between palletized and non palletized goods. In the current situation coloading between the three DC's already occasionally exists on an ad hoc basis. Tables 4 and 5 show the results without taking these loading units with coloading in the current situation into account. First, an important difference in fill rate is noted between palletized and non palletized goods in all three DC's. Second, fill rates in DC2 are lower than in the other two DC's in the current scenario, offering opportunities for bundling freight. The average fill rate in the crossdock increases to 72%. In particular an increase in fill rate of palletized goods is observed. The separate DC's in the crossdock scenario represent loading units for certain export destinations or direct drops.

Table 4: Average fill rate current scenario (%)

	Total	Palletized	Non palletized
DC 1	0.5975	0.4266	0.6428
DC 2	0.4148	0.3672	0.4289
DC 3	0.6844	0.4466	0.7469

Table 5: Average fill rate consolidation scenario (%)

	Total	Palletized	Non palletized
DC 1	0.5045	0.4214	0.5271
DC 2	04223	0.3105	0.4214
DC 3	0.6718	0.4292	0.7516
Crossdock	0.7239	0.6216	0.7753

Results presented are based on the assumption that the current warehouse planning and operations are given. A further improvement in fill rates could be obtained by taking consolidation opportunities in the warehouse planning and operations into account. Finally, simulation results showed that 43% of all loading units are less than 60% filled in the current scenario. This proportion decreases to 36% of all loading units that are less than 60% filled in the consolidation scenario over the time period of the data set.

3.4. Required Number of Loading Units

A final performance measure to evaluate the opportunities of consolidation between the three DC's is the number of loading units necessary for serving all destinations. In the crossdock scenario 2771 loading units are needed instead of 2930 loading units in the current scenario. Clustering freight thus leads to a total reduction of 159 loading units (5%) over a period of ten weeks.

3.5. Statistical comparison of scenarios

Table 6 reports the 95% confidence intervals for differences in performance measures between the current scenario and consolidation scenario. No significant differences in capacity utilization are recorded, as the number of gates in the future scenario is chosen to match the service level in current operations. In Table 6 confidence intervals for differences in throughput time and fill rates are given.

Table 6: 95% confidence intervals

	Confidence interval current - consolidation
Throughput time	
DC 1 - Crossdock	0.1032; 1.0391
DC 2 - Crossdock	0.1493; 1.5293
DC 3 - Crossdock	0.0402; 1.8604
Total fill rate	
DC 1 - Crossdock	-0.2284; -0.0243
DC 2 - Crossdock	-0.3913; -0.2268
DC 3 - Crossdock	-0.0964; 0.0173
Fill rate palletized	
DC 1 - Crossdock	-0.3597; -0.0301
DC 2 - Crossdock	-0.3905; -0.1182
DC 3 - Crossdock	-0.3261; -0.0239
Fill rate non palletized	
DC 1 - Crossdock	-0.2784; 0.0132
DC 2 - Crossdock	-0.4404; -0.2525
DC 3 - Crossdock	-0.0893; 0.0324

First, the organization of a crossdock to consolidate freight of multiple shippers leads to a significant reduction in average throughput time of loading units compared to the current situation in all three DC's. The throughput time depends on the warehouse planning and operations. Considerable time may pass between the arrival in shipping of the first and last load order destined for the same loading unit. Time lags also occur between the arrival of the first and last carton of a single load order. However, through consolidation a significant reduction in throughput time and standing time of loading units may already be realized.

A second performance measure reported in Table 6 is the total fill rate. The fill rate increases significantly in the crossdock scenario compared to current operations in DC 1 and DC2. In particular, fill rates in DC 2 are lower than in the other two DC's in current operations, offering opportunities for bundling freight. However, no significant difference in total fill rate is noted for DC 3, as loading units served in this DC already demonstrate on average a higher fill rate compared to the other two DC's in the current scenario.

Finally, table 6 mentions the 95 % confidence intervals for the fill rate of palletized and non palletized freight. Significant differences are found for palletized loading units, indicating that the crossdock also offers the opportunity to increase the fill rate of loading units containing pallets.

4. CONCLUSIONS AND FUTURE RESEARCH

This paper investigates clustering of freight at the operational level. Potential benefits of shipper consolidation are quantified by means of discrete event simulation. Simulations are performed for a realistic situation consisting of three distribution centres.

First, a significant reduction in throughput time of loading units is realized in the consolidation scenario, making use of a crossdock. Second, the fill rate of loading units may be improved by consolidating freight of shippers inside a loading unit. A higher fill rate implies a better utilization of transport equipment. This may on the one hand reduce the costs of pre- and end-haulage by road or on the other hand increase the attractiveness of intermodal freight transport for further continental distribution. Third, simulation results show that the available gates are used at full capacity during only a limited period per day. Capacity gains can be realized through a shift to non peak periods. Finally, the consolidation scenario leads to a reduction in number of loading units necessary over the observed period.

These simulation results show the opportunities of bundling freight without a change in planning. In both scenarios the warehouse planning and operations are assumed to be given and serve as an input for the simulation model. Further improvements in performance measures would be possible with the introduction of smart planning rules aimed at taking maximum advantage of consolidation opportunities.

Based on these simulation results, external cost calculations of the different scenarios will be presented in future work. Future research may also investigate the relations between customer demand, warehouse planning and shipping operations. Finally, consolidation of freight and the organization of a crossdock imply managerial changes. A revision of business models may be necessary.

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SIMULATION OF THE PASSAGE OF CONTAINERS THROUGH LE HAVRE SEAPORT

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ABSTRACT
The huge volume of shipping containers leads to seeking a better performance of all container terminals in a seaport. Container terminals are spaces for transiting goods from origin point to a destination point. In recent years, several studies on seaport performance have been done to develop new optimization strategies and decision-making tools. After a description of a maritime environment as a state of the art, follows a flexsim-based simulation model of the flow and the massified transport of containers. This discrete-event Flexsim simulation is proposed to validate the massified transfer scenarios of containers from and to the future multimodal terminal of Le Havre seaport.

Keywords: Simulation, Seaport performance, Massification of flow, Flexsim, Multimodal terminal

1. INTRODUCTION

Nowadays, maritime transport plays an important role in the economic world. This emphasis is justified by the evolution of increased volume of shipping freight. Given this economic context, the seaports must be more powerful than before. For this purpose, the total or partial automation in seaport terminals is needed. Indeed with the era of new information technologies and communication, we are willing to keep pace and optimize the tasks of thousands of people who repeat the same things day after day. For instance, let us take the case of the seaport of Le Havre, the seaport Authority plans to construct a multimodal terminal (Benghalia, Boukachour, and Boudebous 2012). The project involves conducting a feasibility study for the technical, economic and socio-economic innovations to massify transportation of containers by railways between marine terminals and the futur multimodal platform. The goal is also to design and carry out news railway structures that consume less space with, significantly cheaper investment and exploitation. It is therefore necessary to look for a different time saving from the transfer scheme, and also sufficient fluidity to movement that transfers are common. Our research aims to design flexsim-based simulation model for analysis and performance evaluation. The objective is to obtain a sufficient frequency and an acceptable cost for such transfers between marine terminals and the multimodal terminal. In practice, the evaluation of seaport performance is a complex problem. For this problem, the criteria that need to be optimized can be classified into two categories (Benghalia, Boukachour, and Boudebous 2012):

1. Those related to the investment cost need to design a terminal (average cost per container, number of quay cranes, number of straddle carriers, and number of storage areas ...).
2. Those related to the productivity of the future multimodal terminal (dwell time of containers, waiting shuttle, ship turnaround time...).

Our research objective is to simulate the seaport passage of container in order to propose scenarios that optimize the performance of container terminals. Indeed, we interest in conducting a simulation model to propose scenarios for container transportation between the future multimodal terminal and container terminal seaport of Le Havre via discrete event simulation to describe the changes of states at precise moments in time following the occurrence of specific events. In this paper, we show our flexsim-based simulation model. In Section 2, a description of the container terminal with different management policies are presented. Section 3 presents the process of seaport transit containers and related works. In Section 4, after the presentation of the project Multimodal, follow a short state of the art about simulation and simulation tools and the implementation of our model. Results are presented in Section 5. Section 6 concludes the paper.

2. DESCRIPTION OF A CONTAINER TERMINAL

A container terminal is an equipped place for the handling and the storage of containers for both import and export processes. It is a set of platforms for the arrival and departure of ships, storage areas and resources for transport and the various operations associated with the handling of containers. Doing these operations involves the participation of different actors:

- Docker: the person who loads and unloads the ship.
- Inland transport: the person who carries (transports) the containers at the terminal.

- The port operator: the person who controls the operations within the seaport. It could be a public authority (seaport authority) which administrates the seaport and control the operations within the seaport.
- The terminal operator (stevedore): the person who takes care of the preparation (legal and material) of the receipt, movement and storage of marine cargo.
- The owner (shipping line / alliance): the person who provides transportation of goods by sea.
- The consignee: the person who is attached directly to the owner, he must ensure every operation for the receipt or delivery of goods and accomplish the tasks entrusted by the owner.

Each container terminal must have the following components:

- Quays: arriving and departure place of ships.
- Yard: space destined for storage of containers.

To perform the handling, container terminal needs other resources that vary according to management policy of each terminal. In general, there are three different possible ways of management (Meriam 2008), for a Marine Terminal:

- Management Mode based on cranes: in fact this type of crane can move and navigate through the rows of cells depending on the location of containers for the current operation. Then the crane loads the searched container into the vehicle that will transport it to a quay crane (these tasks are executed in reverse order in import case).
- The second method of management or also called the alternative system is based on the use of straddle carriers ("yard machines") that are very expensive and require considerable space for their operation. In fact, a straddle carrier truck is able to load, unload a container or search a container and transport it to quay crane.
- The third mode is no longer applied; it requires a large space, although it facilitates the operation of the terminal. It stacks all the containers on chassis to transport them to the porticoes.

Good management of a seaport depends on the optimization of different processes within its terminals. In fact at the level of design and management of container terminals, several problems emerge. Several studies concerning the optimization of seaport operations which are based on simulation and operations research methods have increased (Meriam 2008; Meer and Van der 2000). These studies generally focus on specific problems such as scheduling a type of equipment, assignment of vessels to the docks or the optimization of storage space etc. Our case study concerns the future multimodal container terminal in Le Havre seaport which differs from a normal container terminal because at least two different modes of transport are used. Goods transfer can be done then by train, barge, and truck. Multimodal transport increases the competitiveness of a container terminal.

3. PROCESS IN A CONTAINER TERMINAL

After analyzing various handling activities in a container terminal and according to the work of (Meriam 2008), import and export process in a container terminal can be described as a series of events which can be classified into four levels (See Figure1) (Verjan 2010):

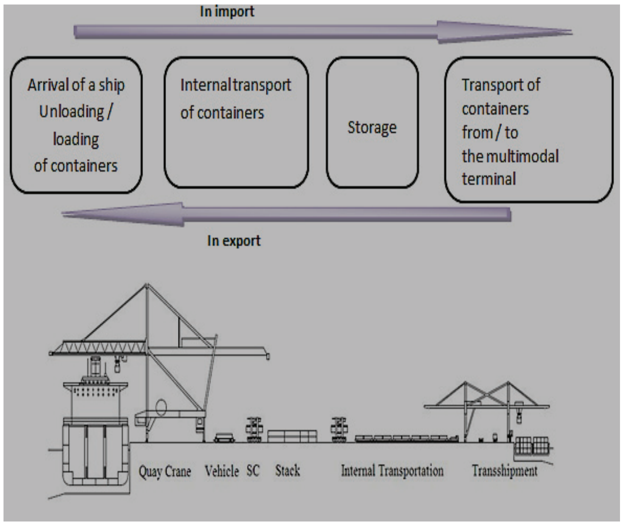

Figure 1: Process In A Terminal.

1. Maritime interface: this step is the point of departure and arrival of ships. In import and at the arrival of a ship on the quay, the relevant actors mobilize for unloading after performing various security controls concerning the container. In fact, at each quay crane an officer or a video system monitors the registration of the container and clarifies its position. For export, the same actors and resources are mobilized to perform the same operations in reverse order. Minimizing the time spent by a ship at the terminal is one of the criteria most studied in recent years. Several research studies have focused in this process (Legato and Mazza 2001) to deal with optimization problems concerning the planning for ships which involves the allocation of berths, storage of containers, and the allocation of gates (or see Gantry Crane).
2. The area of internal transport of containers: at this stage the containers are transported by vehicles from the cranes to the storage areas (Stack) and vice versa for the case "export". The optimization of each activity in this stage

plays a very important role in optimizing the entire chain of handling. Several methods have been proposed by (Meer and Van der 2000). A mixed linear program was developed by (Zehendner, Nabil, Stéphane, and Dominique 2011) to determine an optimized allocation of resources. The goal is to minimize the possible modes of land transportation while respecting the imposed delay of ships. Hartmann has proposed a genetic algorithm (Hartmann 2004) to minimize the average delays of tasks of straddle carriers, automated guided vehicles (AGVs), stacking cranes, and workers respecting the precedence constraints and the constraints of setup times for the Hamburg seaport. Behrokh and Asef-vaziri have developed a simulation model based on the storage systems configuration (automated loading and unloading) and automatic transport vehicles (AGV-ACT) (Behrokh and Asef 2000). They compare the performance of the new configuration with the old one. Finally, the results show that automation is feasible and has a significant impact on operational performance.

3. Storage area: storage areas are composed by a number of rows (channels) called bays allowing the stacking of containers. They can be equipped with cranes (Cranes), fork lift trucks, straddle carriers, etc. Several research studies (Meriam 2008) focused on the optimization of a storage area, Zhang and al are interested in minimizing the distance between the storage area (yard) and berths for the seaport of Hong Kong by providing a decomposition of the problem into two subproblems (Zhang, Liu, Wan, Murty, and Linn 2003).
4. The transfer zone of containers or land side interface: After a period spent in the storage area, the stored containers will be loaded by cranes to transport them through waterway, rail or land. Our study concerns the massified transportation of containers between maritime terminals after spending the previous steps. In fact we will present the multimodal project and our approach to simulate the transfer of containers by train.

4. CONTAINER TERMINAL MULTIMODAL OF LE HAVRE

The multimodal project is one of the major projects of Le Havre seaport. It concerns the transport of containers between different container terminals and the new multimodal terminal. Specially, the flow of containers is between the multimodal terminal and the terminal Atlantic on the one hand, and secondly, between the multimodal terminal and the terminal port 2000 (See Figure 2). The objective is to build a simulation model for describing the transfer of containers between some container terminals and the future multimodal terminal. We have designed a simulation tool in order to validate some containers transfer scenarios. The simulation is based on the software Flexsim (http://www.flexsim.com/). It is designed to model and simulate the evolution of the physical flow within a seaport. It also offers great possibilities for reuse in developing and presenting in 3D mode. It is an object-oriented tool adapted to model and simulates the flow of containers in seaport terminals and the process of passing through its seaport thanks to its library CT (Container Terminal).

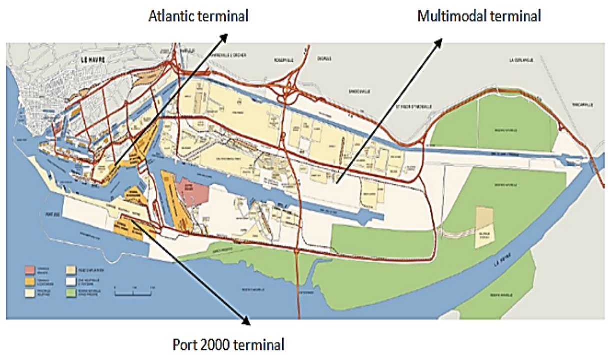

Figure 2: Le Havre Seaport.

4.1. Simulation

Simulation is the development of experiences of a model (Bernard, Herbert, and Tag Gon 1976). It allows the representation of a real system, to assess its performance and the properties of its behavior. Moreover, the simulation can be used to size a system, improve the utilization rate of equipment and also demonstrate the potential of the installation of new equipment. Simulation-based approaches based allow dynamic modeling of behaviors of the company, with varying degrees of constraints and different policies. They can deal with various contingencies caused by the uncertainties of supply and demand. They cannot generate a solution by themselves; they can only run models using parameters and conditions prespecified. Generally they are used to evaluate and compare different possible scenarios. Fredrik and Mirko argue that the simulation allows to take into account the dynamic of systems, to facilitate modeling and capturing the complexities and uncertainties of the analysis of the supply chain (Fredrik and Mirko 2007). (Yuh-Jen and Yuh-Min 2007) propose a modular approach to model and simulate the process of supply chain taking into account the communication system, information and knowledge. They use the simulation tool SIMAN and C++ language to develop the simulation generator.

Many models and algorithms have been developed to address decision problems in container terminals to help improve operational efficiency. The simulation has been widely used to study processes in container terminals. (Kia, Shayan, and Ghotb 2002) use simulation to compare two statistically different operational systems and propose an operational method to reduce congestion and increase the terminal capacity. (Nam, Kwak,and Yu 2002) used a simulation model with four scenarios to examine the optimal size in terms of positions and quay cranes for a container terminal. As for (Demirci 2003), he used the simulation to determine the bottlenecks of the most critical processes in the seaport system, and an investment strategy was developed to balance the load in the seaport. (Lee, Park ,and Lee 2003) developed a simulation model to evaluate seaport operations in a supply chain. Finally (Zeng and Yang 2009) proposed a simulation model for the scheduling of loading operations in container terminals.

In this work, we develop a discrete-event simulation to validate some scenarios of container transportation between terminals taking into account different states (on the road, loading, unloading, busy operator, free operator ...). There are several simulation tools (See Table 1). Our choice was focused on the software Flexsim with its particularity Flexsim CT library dedicated specifically to the simulation of container terminals. Our choice is motivated by the benefits offered through to his libraries. Flexim tool has a wide variety of reporting capabilities including statistics on the docks and storage areas: amount per unit time, queue access doors, cycle time of trucks, use of resources to the docks, etc.

Table 1: Flow Simulation Tools.

Simulation tools	
Simulation tools	specifications
Anylogic	GUI : 2D + 3D Programming language : Java
Arena	GUI : 2D + 3D Programming language : VBA
Automod	GUI : 2D + 3D Programming language : Automod
Plant simulation	GUI : 2D + 3D Programming language : Simtalk
Flexsim	GUI : 2D + 3D Programming language : C++ Library Flexsim CT "For Container Terminals" Data exchange with Microsoft Excel
Witness	GUI : 2D + 3D Programming language : Witness
DelmiaQuest	GUI : 2D + 3D Programming language : C++

The performance of a container terminal has been studied intensively in recent years to develop new optimization strategies and tools for decision support. In practice the evaluation of seaport performance is a complex task because the criteria to optimize are related directly to the investment cost (cost per container, number of quay cranes, number of straddle carriers and number of storage areas ...), and by productivity (dwell time of containers, waiting times for shuttles ...).
Table 2 shows some of the criteria cited in the literature (Verjan 2010):

Table 2: Performance Criteria.

Performance criteria	
Average Cycle time	To measure the performance of loading and unloading operations (movements per hour).
Throughput	Average number of movements per hour for a crane
Throughput par acre	Criterion used to consider the field because it is a limited resource.
Ship turnaround time	Time taken by a ship in berth.
Truck turnaround time	Time spent by a truck in the terminal. This time does not consider the time of trial in the gate.
Gate utilization	Percentage of time taken to serve the traffic inbound and outbound of containers.
Container dwell time	Residence time of a container in the terminal before being transported
Idle rate of the equipment	Percentage of idle time of equipment.
Average cost per container	This is the average cost per container. This is one of the most important measures of cost.

The choice of the passage of containers though the seaport is justified by the fact that this link is part of almost the all of the supply chain. The complexity of this link requires a comprehensive assessment of its performance. Indeed, the performance cannot be restricted solely to the sum of performance of different entities, considered independently of each other, but it is necessarily based on overall approach. The life cycle of our application involves the following steps. Indeed our approach (See Figure 3) is structured in four phases:

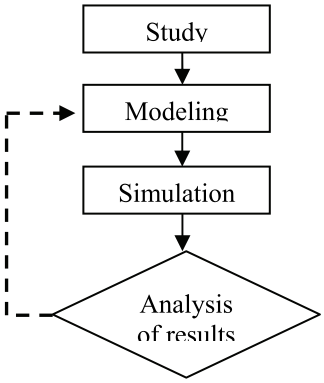

Figure3: Approach.

We simulate the start shuttles multimodal terminal, container terminal at the arrival, loading and unloading of containers and finally the arrival of the multimodal terminal shuttle. The first task was to convert the plan of Le Havre seaport from dwg format to dxf format supported by Flexsim. Then we use Rail API Library (http://nordgrenhome.com/community/forum/downloads.php?do=file&id=127) to build railway, wagons and trains, the first railway is between the multimodal terminal and the terminal of the Atlantic and a second railway connects the multimodal terminal to the terminal port 2000 (See Figure 4). This API is used to size the convoys of cars, track to track, simulate the movement of convoys and operations of coupling and uncoupling cars.

The next step was to model each container terminal, rails and coupons cars (See Figure 5).

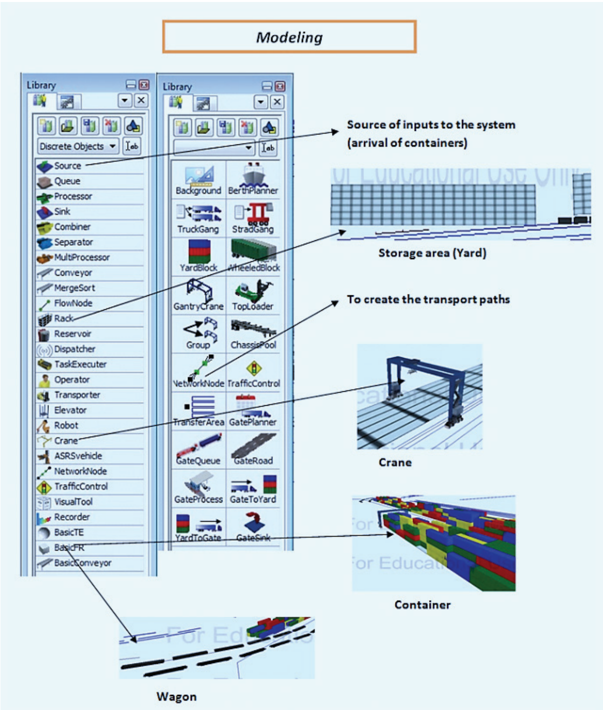

Figure 4: Modeling

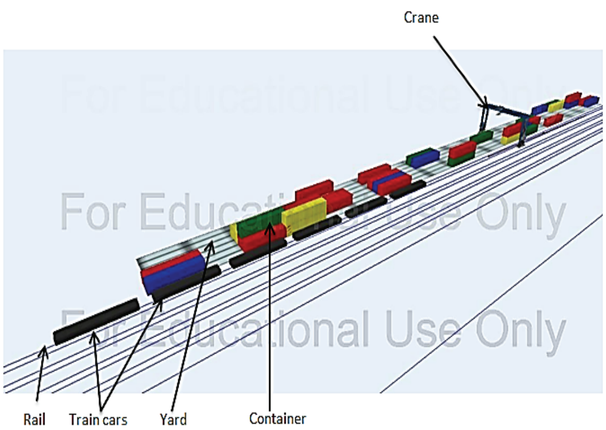

Figure 5: Terminal Container

5. RESULTS

The simulation can be started either by planning the input of containers into the system through a predefined distribution or by imported data from an Excel file containing, among other, the identifiers of containers, their initial position, destination, their date of departure and arrival.

After completing the simulation, Flexsim CT allows to generate a database containing the results. Analysis of the results leads to an improvement of the modeling of our simulation model following the approach outlined above.

Each row in the table represents a single object in the model. The first column contains the path of the object in the simulation model and the second column shows the class of the object. Each of the other columns shows the utilization percentage, the percentage of vacancy or blocking ... of each object. Then through the column travel empty offset and the column travel loaded offset, we can compare the cranes relative to the percentage indicating the movements made (moving: crane in loaded mode or empty crane), which will eliminate unnecessary movements. (See Figure 6).

State Report

Model Stop Time: 44245.48

Object	Class	idle	blocked	generating	offset travel empty	offset travel loaded
/Cranes/Crane_TPO	Crane	97.32%	0.00%	0.00%	1.33%	1.35%
/Cranes/Crane_multi_T	Crane	95.11%	0.00%	0.00%	2.69%	2.20%
/Cranes/Crane_multi_A	Crane	98.18%	0.00%	0.00%	1.00%	0.81%
/Cranes/Crane_atlantique	Crane	97.36%	0.00%	0.00%	1.46%	1.18%
/Terminaux/MULTIMODAL_TPO	Rack	0.00%	0.00%	0.00%	0.00%	0.00%
/Terminaux/MULTIMODAL_TDF	Rack	0.00%	0.00%	0.00%	0.00%	0.00%
/Terminaux/MULTIMODAL_ATLANTIQUE	Rack	0.00%	0.00%	0.00%	0.00%	0.00%
/Terminaux/ATLANTIQUE	Rack	0.00%	0.00%	0.00%	0.00%	0.00%
/Terminaux/TPO	Rack	0.00%	0.00%	0.00%	0.00%	0.00%
/Terminaux/TDF	Rack	0.00%	0.00%	0.00%	0.00%	0.00%
/RailNetworkManager	Dispatcher	0.00%	0.00%	0.00%	0.00%	0.00%
/SourceConteneurs	Source	0.00%	0.00%	100.00%	0.00%	0.00%
/Cars	Dispatcher	0.00%	0.00%	0.00%	0.00%	0.00%
/Yard	Dispatcher	0.00%	0.00%	0.00%	0.00%	0.00%
/Cars2	Dispatcher	0.00%	0.00%	0.00%	0.00%	0.00%

Figure 6: State Report

In Table State Report and for all objects we have 0% blocking which shows the operation of all objects at 100%. Then the subject source has also generated all containers listed in the excel file (Generating 100%).

For the first instance simulated, the cranes were used with a rate between 2% and 4%. The crane of the marine terminal TPO was used with 2.68% whose 1.33% displacement vacuum (It is not a container) and 1.35% displacement loaded. The skull of the Atlantic Terminal was used in which 2.64% whose 1.46% movement of empty (container) and 1.18% of charge movement. At the terminal multimodal, multi skull T is for loading and unloading containers on TDF Marine Terminal (Port 2000). It was used at 4.89% with 2.69% in moving empty and loaded displacement of 2.20%.Finally the crane multi A is for loading and unloading containers on the Atlantic Maritime Terminal. This crane was used at 1.82% including 1% of container movements without and with a rate of 0.81% of loaded movements. These statistical results generated by Flexsim can find performance criteria as the criterion "time vacancy equipment (Idle rate of the equipment): Percentage of idle time of equipment."

The bar graph "current content" shows the statistical results concerning the actual content variable which allows a comparison between the contents of the various terminals. (See Figure 7)

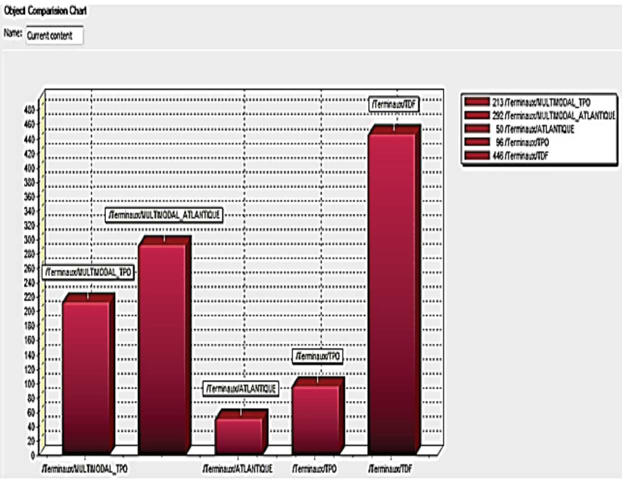

Figure 7: Statistical Results

At the multimodal terminal, 213 containers must be transferred to the maritime terminal TPO and 292 containers must be transferred to the atlantic maritime terminal. There are 592 containers to be transported to the multimodal terminal:

- 50 containers from the atlantic maritime terminal;
- 96 containers from the port maritime terminal 2000 (TPO);
- 446 containers from the port maritime terminal 2000 (TDF).

The figures concerning the flow of containers between the multimodal terminal and maritime terminals are essential for the design of resources necessary for handling and transporting containers.

6. CONCLUSION

This work concerns the transport of containers between marine terminals. The aim of this approach was to develop of a demonstrator and the simulation of the transfer of containers in order to dispose a tool for the achievement and validation of different scenarios. The realization of the simulation model has been based on the software Flexsim especially Flexsim CT. The results obtained allow improve the proposed scenario for the massified transfer of containers.

We are working to develop a simulation model. Le Havre Port Authority wants to rethink the short-distance rail transport on the port domain in the first stage, and the Seine Axis (Paris, Rouen, Le Havre). Thus, Le Havre Port Authority wants to improve implementation and uses trains on the transfer sites in order to increase the performance of these tools and therefore, the performance (delay / reliability / cost) of mass transport:

- For rail cars, more frequencies, less downtime on terminals for related operations such as brake tests.
- For equipment such as cranes and riders, fewer longitudinal displacements.

The objective is to obtain a sufficient frequency and an acceptable cost for such transfers between marine terminals and multimodal terminal.

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SYNCHRONOUS RAILWAY SIMULATION OF SHUNTING YARDS

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ABSTRACT
Capacity analysis using simulation tools is an important factor to support strategic decisions in railway operation and infrastructure development. This work describes a railway simulation tool for shunting yards using a synchronous approach. Latter includes movement generation in simulation real-time and is essential for reduced set-up times, a flexible application for different yard layouts and various shunting strategies. An adequate network graph design was used for automatic routing decisions and methods for deadlock avoidance were implemented. The available approach results in an executable model to be validated with real data.

Keywords: shunting, synchronous simulation, railway simulation

1. INTRODUCTION

Ongoing optimization of railway infrastructure and its operations are important factors to strengthen the competitiveness of railway operators compared to other modes of transport. Investment decisions – especially in the field of railway transportation – tend to have long planning and lifecycle times, respectively and result in high costs for planning, development and maintenance. In many cases such planning problems have to consider the complexity of variables, input parameters and their variability. Due to the complex interactions between the infrastructure to be planned and the shunting processes simulation is seen as a reliable method and planning tool. Nevertheless, nowadays the available simulation tools for shunting yards cannot cope with capacity analysis on a fast and fairly aggregated level. Sufficient set up times are required for scenario analysis, which results in high costs and long cycle times for specific shunting yards. This research closes this gap, as with SimShunt an innovative simulation model structure has been developed that is ready to use for different shunting yards with short set-up times and fairly easy to handle (Hüttler, Gronalt, and Zazgornik 2011). Set up times deal with the infrastructural investigation, flows of incoming and outgoing trains and wagons as well as routing and scheduling within the yard according to shunting strategies and resource allocation.

The existing tools do not allow a strategic network wide view. Currently, the Austrian Federal Railways (ÖBB) who are developing partner use the simulation tool NEMO, but as it only deals with the arcs of a rail network, it is not possible to use it for capacity analysis. The software tool RailSys can be used in combination with NEMO (Kettner, Sewcyk, and Eickmann 2003) and tackles the simulation from an asynchronous point of view. It is possible to simulate planned and delayed train schedules and it allows rescheduling automatically to compare and validate decisions made in reality. Simulation software VILLON can be used for simulating logistic nodes, like plants, ports, railway stations or shunting yards (Kavicka et al. 1999; Adamko and Klima 2008). Sufficient data set up is needed and several months of work are required. Besides this, Marinov and Viegas (2009) work with simulation models for analyzing operations at shunting yards. Deadlock avoidance in synchronous railway simulation is the main aspect in Pachl (2007) and Pachl (2011). Cui (2009) deals with a hybrid simulation model for semiautomatic dispatching of railway operations. The focus is set on processing the synchronous simulation including a solution of the deadlock problem for railway operations. The publications of van Wezel and Riezebos (2005) as well as Riezebos and van Wezel (2009) deal with computing k-shortest paths (Eppstein 1994) for shunting yards. These algorithms are the basis for operational processing of shunting operations and are also used in the SimShunt model. Eggermont et al. (2009), Dahlhaus et al. (2000) and Dahlhaus and Systel (2011) describe sub-problems that occur at a shunting yard. Their work defines problems and their complexity from a mathematical point of view and can be seen as a basis for developing algorithms for practical usage. More complex problems that include more than one sub-problem including mixed integer programming models can also be found in He et al. (2003), Bektas et al. (2009) and Bohlin et al. (2011). Finally, Boysen et al. (2012) present a literature review on shunting yard operations.

The goal of this research is the development of a new simulation approach for capacity analysis of shunting yards using synchronous simulation technique. This method allows building up a generic model with the desired properties of short set-up times, easy scenario variation and various shunting strategies. The time consuming development of a predefined timetable of shunting movements according to strategies is replaced by an automatic real-time decision system.

2. PROBLEM DESCRIPTION

Several characteristics of shunting yards have a direct impact on yard's capacity: Infrastructural equipment, infrastructural resources, their allocation and shunting strategies. In order to take into consideration the most relevant parameters for yard's capacity, the high number of interdependent shunting movements in the complex railway network has to be rebuilt in the model. Therefore, asynchronous railway simulation models use a complete a priori scheduling process. In contrast to that, the SimShunt model realizes a synchronous approach, where every movement is defined in simulation real-time (see Pachl 2007). The benefits are extremely short scenario setup times, easy variation of input parameters and a flexible implementation and use of strategic algorithms. During realization two problems arise: The routing and the even more important deadlock problem. The proposed routing method is based on the k-shortest path algorithm (Eppstein 1994) and needs a special network-graph design to fulfil the requirements for shunting movement modelling. Most relevant characteristics of shunting processes are the great number of reversal movements dependent on train length and signal infrastructure as well as their interdependencies. Furthermore, the movements are bounded to a yard's rail network with short track lengths, large number of switches and tracks of solely bidirectional usage.

Deadlocks can occur for several reasons, like violation of movement sequence and conflicts because of inaccurate routing decisions. Pachl (2011) points out that "*With increasing size and complexity […] the deadlock problem has become more and more evident. Known strategies against deadlocks known for decades from computer science and operations research do not really fit to the specific needs of railroad operations simulations.*" Shunting yards belong to the most complex rail networks, with a very high number of tracks with bidirectional operation. Therefore, the deadlock-problem is a very serious issue and one of the most important facts to provide a fully functional simulation. Our approach, solving the deadlock-problem is to combine synchronous simulation with an asynchronous dispatching logic by means of implementing optimization algorithms.

3. METHODS

Proper routing solutions and deadlock avoidance are the key factors for a successful implementation of a synchronous shunting yard simulation. The methodical approach is described in the following and results in an executable simulation tool using the Software 'AnyLogic' that is ready for validation.

3.1. Network Definition

A network graph is defined consisting of nodes and arcs and is needed as a basis for the automatic generation of shunting movements of train units with variable length. Therefore, the whole track layout is implemented true to scale and exact signal positions and their orientation are included as well. All possible movements on shunting yards are usually available from their operators and documented for terms of security and switch standing. This information is used to generate elementary movements, which represent the arcs in the graph and link the nodes, which are signals, together. The arcs are weighted by the track lengths that the elementary movements contain. Reversal movements are not needed to be listed in real operation, because of their manual treatment by the signal operator. In fact they are dependent on the length of the moving train unit. To include them in the graph, the already existing movements are supplemented by adding a set containing two types of elementary reversal movements. Thus, directional movements are defined and can be triggered by defining the permitted movement types in case of restrictions. Those are required due to the fact, that movements can have defined directions for leaving start signals and reaching target signals, respectively.

3.2. k-Shortest Path Implementation

Based on the network graph defined above, a k-shortest path algorithm (Eppstein 1994) is used to define required routes from start to target signal with additional requirements concerning movement direction, orientation and length of the train unit that has to be transferred. During shunting operations tracks and signals have to be excluded from routing algorithm, because of resource assignments to other operations or occupation by other train units. Furthermore, in some cases it is necessary to overrule the finding of the shortest path or enforce the use of a particular track sequence. Maybe Loop tracks have to be used for changing train orientation in the system or the correction of long distance routes is required in case of arrivals and departures. For example latter occurs in a curved yard layout, as the shortest routes are the ones containing tracks near the inside radius, which possibly leads to conflicts with other operational instructions. Hence, modifications were made in terms of restraints defining optional signals to be included in the route and signals to be removed from graph. Besides that, the weight of a route has to be modified dynamically according to the train length and a variable penalty to charge the effort of reversals. For complexity reduction reasons some simplifications are made concerning track occupation and assignment to signals. In the present model every non moving train unit in the system is assigned to a signal and has to be coupled logically to those assigned to the same signal. Accordingly there is just one train unit located at a signal and assigned to each signal besides shunting engines.

3.3. Deadlock Avoidance Strategy

To avoid deadlock occurrence at first stage, a route reservation strategy was implemented. Because almost every track in the shunting yard is of bidirectional use, they have a high potential of conflicts, leading to deadlocks in the simulation system easily. One possible solution is to guarantee movement execution from start to target signal and avoid stops in between. Therefore, tracks are classified into two types. Capacity tracks are able to allow train units to stop at their signals, which act as start and target signals. The remaining ones are connecting tracks, where stopping is prohibited besides reversals. Their signals are used for routing purpose only. To guarantee conflict free operation and correct sequence of task execution on capacity tracks, a second reservation procedure is applied. Operational tasks according to the shunting process need to reserve capacity tracks involved in their movements included in their execution process. Depending on their explicit action, this reservation has to take place at task start-up or during operation successively. This reservation procedure turned out to be too restrictive in terms of capacity loss because of too long periods of pre-reservation, especially during long distance moves. To face this problem, an optimization based algorithm is implemented in the model. A mixed integer programming model (MIP) was formulated, to add an asynchronous despatching logic scheduling movements in waiting position. It guarantees a conflict free dispatching. Since this method is used within the simulation a fast computation is needed, which is often in conflict with the combinatorial complexity of such models. Therefore, an iterative approach was chosen and the MIP-model is solved repeatedly every time a new movement is ready to dispatch and results in assign- and reassignment of movement start times

3.4. Control Unit Further Research

Shunting movements have to be generated out of the running simulation in real-time. Therefore, decisions for track allocation and humping sequence have to be taken into account. This is done by using optimization methods, namely exact and heuristic ones, which are developed and embedded within the simulation model. Two steps are performed to develop the complete simulation framework. First, heuristic rules are developed for the test shunting yard to validate the model with current best practice. Second, more advanced decision rules are implemented to allow generic decisions, independently for different shunting yards and layouts.

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MESOSCOPIC SUPPLY CHAIN SIMULATION

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ABSTRACT
Supply Chain Management has become a highly strategic discipline that can make up a substantial competitive advantage for every organization in globalized, intertwined logistical networks. Due to the complexity of today's supply chains, simulation has become a powerful tool in order to increase the supply chain's resilience and robustness as the major objectives of supply chain management. This paper compares existing approaches for supply chain simulation and shows the advantageousness of a mesoscopic approach for supply chain simulation. Major benefits of the mesoscopic approach are its flexibility, speed of modeling and simulation and ease of use. Mesoscopic simulation models can be used both in the planning phase and during the operation of the supply chain. Combining elements of continuous simulation and discrete-event simulation, the mesoscopic approach facilitates modeling and simulation of many real world supply chain problems. Modeling efforts are balanced with the necessary level of detail of the output data that is needed for calculations of key performance indicators in order to evaluate the supply chain performance.
The paper applies the mesoscopic modeling and simulation approach using the simulation software MesoSim, an own development, in order to show its advantages.

Keywords: Supply Chain Management, Supply Chain Simulation, Mesoscopic Simulation

1. INTRODUCTION

Supply Chain Management is an increasingly complex discipline that includes operational, tactical and strategic decisions between different stakeholders regarding physical material flows as well as information and finance flows covering all organizational functions. (Keith and Webber 1982) Modeling these supply networks is a powerful way in order to (1) increase understanding of the system behavior, (2) develop a strategic solution to a specific organizational problem or (3) utilize models for planning purposes on an ongoing basis. These decisions always aim at the major objectives of supply chains that are resilience, the capability to respond to variations, and robustness, the capability to withstand environmental changes. (Chopra and Meindl 2008)

The benefits of supply chain modeling have been acknowledged in scientific and industrial environments and in consequence, during the last two decades there has emerged a variety of different modeling approaches including deterministic optimization models, stochastic simulation models (Jain and Leong 2005), hybrid simulation-optimizations (Hicks 1999) and information-technology driven models that are focused on real-time integration of organizational big data as classified in (Min and Zhou 2002). There has not yet emerged a dominant approach for supply chain modeling, however, and the existing variety makes the selection of the best modeling approach a non-trivial task. (Anderson and Morrice 1999) In general, there can be distinguished solution generation approaches that are rather mathematical optimizations and solution evaluation approaches that are simulations. Mathematical optimization models are not able to incorporate variations in time but only find stationary optimal solutions which in practice are less important within the area of supply chain management. (Kleijnen and Smits 2003) Simulation models are identified as the superior approach, because they allow for reproductions of highly complex systems, any desired level of detail or aggregation and replication of stochastic, dynamic behaviors.

Simulation techniques are manifold and the absence of an approach that fits every supply chain problem results in a proliferation of supply chain simulation methods that are tailored to certain problems of supply chain management such as supply chain design, production planning and scheduling, inventory control, transportation and logistics management, risk management and inter-organizational coordination, cooperation and integration. This paper compares and classifies these approaches, methods and tools in order to match supply chain questions with the most appropriate simulation that meets the user's objectives.

This paper will be structured as follows: Section 2 will provide a description and comparison of the major simulation approaches that are currently used for supply chain simulations. Section 3 will describe the mesoscopic simulation approach and will show the advantageousness of this approach for supply chain simulation. Section 4 will present the results of a simulation study that shows the flexibility, ease of use and speed of mesoscopic supply chain simulation.

2. SUPPLY CHAIN SIMULATION - REVIEW

The scope of supply chain management includes strategic, tactical and operational problems within and between organizations. Typical questions within the area of supply chain management are capacity planning, resource planning, lead time planning, production planning, inventory management, sourcing strategies and information sharing implementations. The variety of problems within this area has caused the emergence of many different simulation approaches. Simulation approaches can be distinguished based on characteristics such as scope (macro-, meso-, microscopic), time (continuous, discrete, hybrid), orientation (object-, process-, activity-oriented), input-data required and output data generated. This paper will compare major approaches that are subject to discussion within the field of supply chain simulation.

Discrete-Event Simulations are widespread in industrial and logistical environments and there is a broad spectrum of software for very specific purposes as well as general purpose software. Discrete-event simulations provide very detailed information, but are related to high input data quantities and requirements, high modeling efforts and high calculation times. (Scholz-Reiter, Beer et al.) In addition, the high level of detail of the data generated most often is not needed by the user. (Min, Zhou, 2002) Supply chain applications can be found in (Alizadeh, Eskandari et al. 2011) who test the impacts of stochastic lead times, demands and item life times on a simple inventory-system with a discrete-event Arena-model or in (Ingalls and Kasales 1999) who test and evaluate the service levels and profitability as major performance indicators for different supply chain configurations using a three-echelon Arena-simulation model.

System Dynamics was initially developed by Jay W. Forrester in 1961 and is based on causal loop diagrams, stock and flow diagrams and delays to model the behavior of complex systems. This approach has been utilized in many different disciplines like physics, biology, energetic or environmental issues and social systems, but has recently also been applied to supply chain modeling. Different supply chain models are described in (Angerhofer and Angelides 2000). (Ashayeri and Keij 1998) use system dynamics modeling for business process reengineering and (Campuzano and Mula 2011) discuss performance evaluation and improvement based on a simulation model. System Dynamics is a strategic long-term oriented approach and provides output data on aggregated levels only, but requires much less modeling efforts than discrete-event simulations. Dynamic feedback processes determine long-term system behaviors and system dynamics is a powerful tool to create understanding and initiate organizational change. Due to the high level of aggregation continuous simulation models are inappropriate for operational supply chain problems such as planning and scheduling, allocation or routing problems.

Simulation-Optimization is a young approach that is described in (Abo-Hamad and Arisha 2011; März, Krug et al. 2011). This approach suggests an iterative procedure of alternating simulation and optimization. Therewith, it removes the inherent weaknesses of optimizations to not incorporate variations in time and simulations of not generating optimal solutions. The combination supports supply chain decision making by generating optimal solutions that in addition are robust and resilient over time. This approach, however, requires high levels of skills and sophistication. Developing the interaction of these models is a logically and technically complex task. Modeling efforts as well as calculation times are very high and the necessity of the data generated needs to be assessed and evaluated in advance because it often goes beyond the necessities for supply chain problems. Supply chain applications can be found in (Better, Glover et al. 2007) dealing with the field of risk management and in (Hicks 1999) presenting a four-step procedure for supply chain design questions.

Pure spreadsheet based simulations as described in (Powell 1997; Plane 1997; Kleijnen and Smits 2003) are per se deterministic and static. Even though these attributes are contrary to the goal of modeling very complex dynamic behaviors of supply chains, spreadsheets have introduced simulation to the industrial environment as the required skills and scientific backgrounds for implementation are much lower and spreadsheets are very commonly used in industrial environments. Supply chain topics of inventory management and transportation and logistics can be addressed with spreadsheet simulations (Chwif, Pereira Barretto, and Saliby 2002) develop a spreadsheet based model to dynamically determine safety stocks in supply networks and therewith even incorporate dynamic behavior. Monte-Carlo simulations as add-ons to spreadsheet-based simulations introduce stochastic elements to the deterministic environment wherefore they are more appropriate for supply chain simulations. (Deleris and Erhun 2005) suggest Monte-Carlo simulation as a technique to improve risk-management within supply chain management as one specific aspect of the complex and comprehensive system. Spreadsheets based simulations and Monte Carlo simulations are both appropriate measures for certain aspects of supply chain problems, but they do not incorporate dynamic behavior which is essential in supply chain management.

3. MESOSCOPIC SIMULATION APPROACH

In order to overcome the described disadvantages of existing approaches to supply chain simulation (Reggelin 2011a) and (Reggelin and Tolujew 2011) have developed a mesoscopic approach to modeling and simulation of logistics networks and the mesoscopic simulation software MesoSim.

Mesoscopic models represent logistics flow processes on an aggregated level through piecewise constant flow rates instead of modeling individual flow objects. This assumption is valid since logistics flows do not change continuously over time because the control of resources is not carried out continuously but only at certain points of time like changes of shifts, falling below or exceeding inventory thresholds. (Reggelin 2011a) The resulting linearity of the cumulative flows facilitates event scheduling and the use of mathematical formulas for recalculating the system's state variables at every simulation time step. (Reggelin 2011b) The simulation time step is variable and the step size depends on the occurrence of scheduled events. This leads to a high computational performance. (Schenk, Tolujew et al. 2009)

In terms of level of detail, mesoscopic simulation models fall between object based discrete-event simulation models and flow based continuous simulation models. (Schenk, Tolujew et al. 2010)

The appropriateness of this approach for supply chain simulation is based on the inherent characteristics of supply chains.

- Supply chains deal with flows of materials and information on an aggregated level. Single logistics objects are of secondary interest.
- Supply chains include both continuous processes (e.g. continuous inventory reduction) and discrete impulse-like flows (e.g. event-based inventory replenishments).
- Supply chains include different products and product portions that must be representable in the simulation model. In mesoscopic models, different product types run in parallel through all nodes and edges of the supply chain.
- Supply chain complexity requires both simplification and efficient calculation algorithms as offered by the mesoscopic approach by using mathematical formulas to calculate the results as continuous quantities in every modeling time step.
- Supply chain performance evaluation occurs on a mesoscopic level. Neither aggregated results of a macroscopic simulation nor detailed primary data of a microscopic simulation can be utilized without being transformed into mesoscopic metrics (throughputs, cycle times, utilizations,..)
- Supply chain data is available on aggregated levels. For discrete-event simulation, detailed data needs to be deducted and for system dynamics, the level of detail is even reduced. Mesoscopic simulation directly utilizes available supply chain data.

4. MESOSCOPIC SUPPLY CHAIN SIMULATION IN PRACTICE

4.1. Supply Chain Description

The simulation study is based on a real-world supply chain of a company that designs, manufactures, markets and services consumer goods. The production of these products is outsourced and executed by suppliers that are located in Asia. Production times vary depending on the product with known fluctuations. Suppliers are grouped into strategic suppliers and others. Via distribution centers, products are transported to warehouses and locally sold and delivered to customers. Even though the sales prices for the products are the same for all customers, there are strategic customers accounting for 80% of sales and secondary customers purchasing the remaining 20%. Main supply routes pass distribution centers that are located in European countries. Three modes of transportation are used namely truck, railroad and sea transportation. The transportation is executed in accordance with minimum batch size constraints. The minimum lot size for transportation is one container that can contain different group packs of product types. The products are classified based on the desired service-levels. The warehouses are geographically distributed across Europe. The main objective of the company is an inventory level optimization at its warehouses and distribution centers under the condition of realizing as few goods movements as possible. The structure of the supply chain is illustrated in Figure 1. The mesoscopic simulation model aims at rebuilding the supply chain configuration in order to prepare a risk analysis of deterministically defined safety stock levels.

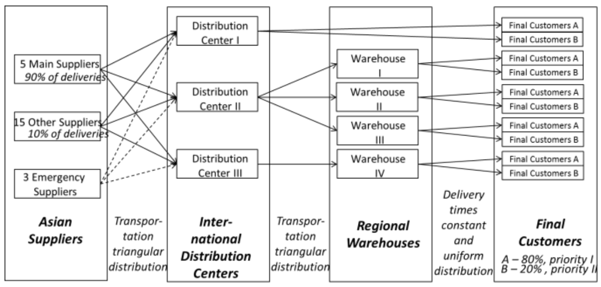

Figure 1: Supply Chain Structure

4.2. Modeling with MesoSim

Basic elements of the mesoscopic simulation model are source, sink, funnel, assembly, disassembly and delay. The mesoscopic approach supports modeling different product types and portions that can flow in parallel through the system because of multichannel funnels and delays. In addition to piece-wise constant flows, a mesoscopic model may employ impulse-like flows to represent the flow of logistics objects through a logistics system. These elements are utilized to replicate the structure and processes as described for the supply chain.

4.2.1. Structure

Funnels are main structural elements that represent suppliers, distribution centers, warehouses and customers within the model. Funnels are parameterized through output flow rates and impulse-like outputs for each product type, opening inventories, constraining performance limits and proportional distributions of outputs to successional elements. Delays are used to imitate transportation and delivery times. Parameters of delays are constant or variable lag times and output allocation to successors. Assembly and disassembly imitate material handling and (de-) composition of logistical units at distribution centers or warehouses. These elements are defined by parameters of funnels and in- and output percentages. The distribution network modeled comprises four vertical stages and up to four horizontal stages and is illustrated in Figure 2.

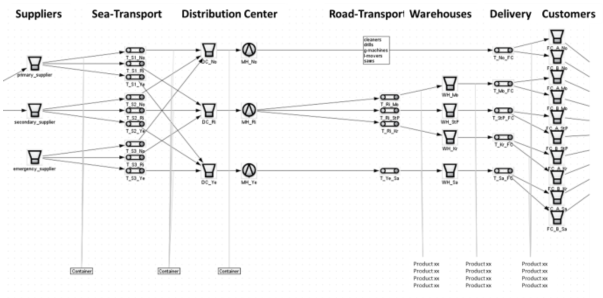

Figure 2: MesoSim Supply Chain Model

4.2.2. Processes

Processes in MesoSim are replicated through piece-wise continuous and impulse-like flows to represent the flow of logistics objects through a logistics system. Impulse-like flows allow representing bundled movement of logistics objects like bundled transports or the movement of production batches. The creation of the actual simulation model requires input data from the real system. The input data needed for mesoscopic simulation is aggregated and includes average production times and volumes for each product type with the respective fluctuations on a periodic level, shipment and production batch sizes, average processing performances of the structural elements, probabilities of risks and estimations of demand distributions. Information at this level of aggregation can directly be implemented in the MesoSim model.

Based on this information, the following supply chain processes are incorporated in the simulation model.

- Suppliers continuously produce different products and once a certain quantity is reached they ship them in containers to distribution centers.
- Production times for all products are normally distributed with defined average values and standard deviations.
- Sea-transportation lead times to distribution centers are based on triangular distributions.
- At the distribution centers, material handling of containers is imitated and product types can be newly combined for further distribution. Uniform distributions are assumed for material handling times.
- Transportation from distribution centers to warehouses is replicated using delay elements with triangular lead time distributions.
- At the warehouses, another material handling is imitated and product types are distinguished to allow for different demands. Constant material times are utilized.
- Demands are imitated by defining continuous output flow rates at each warehouse as well as impulse-like increases.

4.2.3. Scenarios

The development of inventory levels of all products at the final warehouses under certain conditions is of main interest for this simulation model. Major risks for supply chains can come from customer side as well as from supplier side wherefore both is imitated demand and supply uncertainty. Two scenarios are tested and inventory level developments observed.

1. The short fall of one supplier should be captured by others. Within the experiment, replenishment of one product type at a distribution center is halved compared to the regular situation and the impacts on inventories at final warehouses are assessed.
2. Impulse-like demand increases stress-test the supply chain at certain points of time. Imitating major contracts in form of large-scale orders illustrate impacts on overall inventory levels.

4.3. Results

This simulation was conducted in order to, firstly, show the applicability and advantages of mesoscopic simulation for supply chains and, secondly, realize the replication of a real-world supply chain for inventory development studies under demand and supply risks.

4.3.1. Supply Chain Simulation

The software MesoSim can be utilized for supply chain simulation and allows for modeling of main structures and processes and has certain advantages for supply chain modeling such as level of aggregation, speed and flexibility.

The utilized input data and generated output data for the simulation was on aggregated levels without the necessity of further aggregating or decomposing the data. The creation of modeling is straight-forward and can be quickly realized and calculation through the simulator is fast due to the calculation only at events concerning change of flow rates and the occurrence of impulses. Different scenarios could be imitated and tested and the model will be further adjusted to be used for planning purposes illustrating the flexibility and adjustability of the approach.

4.3.2. Scenarios

The created supply chain model is used to observe inventory developments at final warehouses under certain conditions.

The model is validated based on data derived from the real system. The exemplary inventory developments of two product types in one final warehouse are illustrated in the first diagram of Figure 3.

Based on this supply chain model, two scenarios have been tested in order to observe inventory developments and assess the impacts of uncertainties.

The impacts of a supply shortage of one product (red line) at the preceding distribution center on the final warehouse are shown in the second diagram. Safety stocks are almost depleted until the replenishment from other suppliers begins and stock levels increase.

Demand increases in the form of large scale orders for the second product (blue line) are visualized in the third diagram and show substantial safety stocks to cover these situations.

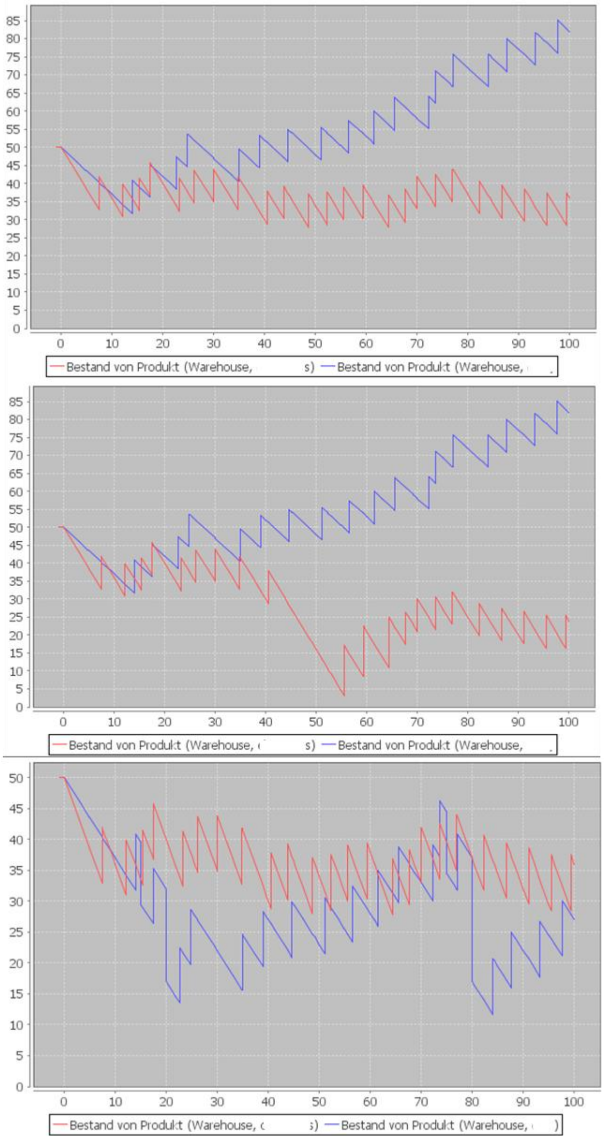

Figure 3: Inventory Developments at Final Warehouse given Supply and Demand Uncertainties

5. CONCLUSION AND OUTLOOK

This paper illustrates the application of the mesoscopic simulation approach to a real-world supply chain example utilizing the software MesoSim. The purpose of this study was to examine the advantages for supply chain simulation that have been expected from this approach. The mesoscopic simulation approach provides three major advantages for supply chain simulation:

- Level of detail: Supply chain simulation is used for key performance indicator calculations. KPIs aggregate data in order to assess and evaluate supply chain performance and identify system constraints. This purpose can be satisfied by mesoscopic simulation.
- Flexibility: Mesoscopic simulation is a generic approach that supports modeling of the majority of different supply chain problems. The adjustability of the aggregation level is essential for supply chain problems that by definition are very complex covering a broad spectrum.
- Speed: Mesoscopic simulation allows quick analysis of supply chains. Modeling effort is balanced with output data needed and calculation time required.

This paper provides both a review of modeling and simulation approaches for supply chain management and the first real-world example of a mesoscopic simulation model. The created model will be further developed to be used for planning purposes also.

More mesoscopic supply chain simulation models are needed to strengthen the results, further develop the software MesoSim and sustainably introduce mesoscopic simulation to supply chain management topics.

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CLASSIFICATION OF NATURAL-TECHNOGENIC OBJECTS IN REMOTE SENSING APPLICATIONS

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ABSTRACT

The major natural-technogenic objects in remote sensing applications are specified in the paper. The paper shows the importance of modern monitoring technologies in order to provide broad picture of the current state of the object and its natural environment as a single system, including the possible changes in the current state and management of the system under normal and emergency modes with the visualization of results of data processing. The goal of the paper is to specify the most important monitoring objects within Latvia-Russia cross-border territory. Practical applications of remote sensing and geoinformation technology in different areas are considered in the paper as well. The worldwide best practices of the different object monitoring are examined and possible objectives, issues and benefits are defined. Some types of natural-technogenic objects are hold out for the further study in order to demonstrate the effectiveness of the developed integrated intelligent monitoring system.

1. INTRODUCTION

Humans have broadened their understanding over the years, about size, shape, and processes associated with earth, which in turn contributed in making sophisticated and accurate representation of the globe and its phenomena. Advancements in space technology, digital information, and communication technologies have stimulated the growth of earth-oriented information science/system, which helps in representing and modeling earth's phenomena in an efficient way (Anbazhagan, Subramanian, and Yang 2011).

It is hard to imagine modern human activities without using precise, independent and recurrently updated information. Satellite-based imagery is the source of such information. Nowadays we are witnessing more and more practical tasks being resolved with the help of remote sensing data (ScanEx 2012).

Natural resource management is a broad field covering many different application areas as diverse as monitoring fish stocks to effects of natural disasters (hazard assessment). Remote sensing can be used for applications in several different areas, including (El-Khoury 2012, Sherbinin et.al 2006):

- Geology and Mineral exploration (quarrying, the coordination of the wells and other resource-mining objects, geodynamics and monitoring of geological environment, deformation and displacement of engineering structures and soils, archaeological research)
- Hazard assessment (storm, flooding, fire, geothermal exploration, earthquake)
- Oceanography (ocean-atmosphere system, sea surface temperature and topography, ocean circulation, sea level variability, wind speed and stress, wave height, solar radiation flux at ocean surfaces, and sea-ice characteristics and ice motion, fisheries)
- Agriculture and forestry (soil properties, crop inventory and yield prediction, vegetation change, assessment of biodiversity)
- Land-use (land degradation, land-use change and sustainability trajectories, urban studies)
- Environmental monitoring (environmental treaties)
- Social Science (demography, human health and epidemiology, archaeology and anthropology, international relations, law and policy)

Geoinformation technologies and remotely sensed data, recently only in hands of large government and military institutions, are actively entering all the fields of the economy data (ScanEx 2012). This imposes new requirements on the dedicated software for remotely sensed data processing. First and foremost the high quality of the output image products should be ensured. At the same time this software should run on ordinary computers of average performance, provide for an advanced set of tools as well as be user-friendly and easy-to-use.

2. SPACE TECHNOLOGY FUNCTIONAL CAPABILITIES

Each application itself has specific demands, for spectral resolution, spatial resolution, and temporal resolution. For a brief, spectral resolution refers to the width or range of each spectral band being recorded. As an example, panchromatic imagery (sensing a broad range of all visible wavelengths) will not be as sensitive to vegetation stress as a narrow band in the red wavelengths, where chlorophyll strongly absorbs electromagnetic energy.

Spatial resolution refers to the discernible detail in the image. Detailed mapping of wetlands requires far finer spatial resolution than does the regional mapping of physiographic areas.

Temporal resolution refers to the time interval between images. There are applications requiring data repeatedly and often, such as oil spill, forest fire, and sea ice motion monitoring. Some applications only require seasonal imaging (crop identification, forest insect infestation, and wetland monitoring), and some need imaging only once (geology structural mapping). Obviously, the most time-critical applications also demand fast turnaround for image processing and delivery - getting useful imagery quickly into the user's hands.

The following main functional capabilities of the technology are required to provide monitoring of natural-technogenic objects:

1. Image filtration:
   - Edge Detection.
   - Smooth filters.
   - Speckle Noise filtering.
   - Morphological operations.
   - Texture features calculation.
   - Noise removal.
   - Values interpolation.
2. MODIS data thematic products:
   - Fire detection.
   - Clouds detection.
   - Snow and ice cover detection.
   - Land surface temperature calculation.
   - NDVI and EVI calculation.
   - Possibility to set threshold values during calculation.
3. Thematic processing of radar images:
   - Radar images segmentation using specific algorithms.
   - Oil spills detection.
   - Possibility to get statistic probability of assessing the pixel as oil spill.
   - Ship detection.
4. Solar radiation balance calculation:
   - Capability to calculate short-wave radiation.
   - Capability to calculate long-wave radiation.
   - Capability to calculate air and surface temperatures.
5. Hydrological modelling:
   - Possibility to model hydrograph.
   - Flooding modelling.
   - Freshets and overflows modelling.
   - Acquisition of water distribution model on the specified date.
6. 3D modelling and visualization:
   - Cloudiness, fogs, mists, smoke modelling.
   - Water surface modelling.
   - Trees modelling.

3. MONITORING OBJECTS CLASSIFICATION

The natural-technogenic objects of monitoring can be divided into three main classes:

1. Environmental and natural resources.
2. Natural disasters and industrial accidents.
3. Technogenic objects.

1. Environmental and natural resources monitoring

The studies of the dynamics of ecosystems changes in varying degrees, study of the influence of various natural and anthropogenic factors on the ecosystem, evaluation of natural resource management regimes etc. Possible objectives are:

Monitoring of ecosystems including:

- aerosols in atmosphere
- air pollution
- water pollution

Monitoring of natural resources, e.g.:

- an inventory of agricultural land
- forecast yields
- soil and banks erosion
- deforestation
- forest inventory
- analysis of rivers, lakes, seas ice cover
- analysis of the dynamics of groundwater
- water content of the rivers and lakes

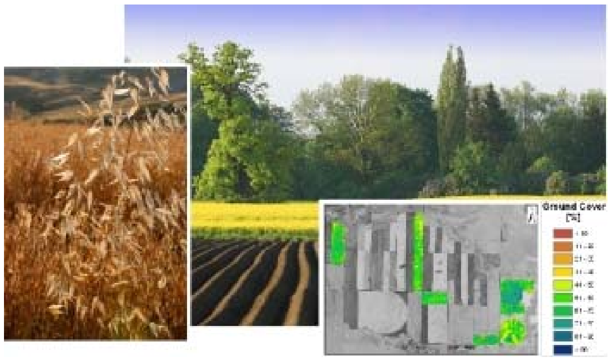

Figure 1: Environmental and Natural Objects

For example, remote sensing is determined as the most accurate tool for global biomass measurements because of the ability to measure large areas. Current biomass estimates are derived primarily from ground-based samples, as compiled and reported in inventories and ecosystem samples. By using remote sensing technologies, we are able to scale up the sample values and supply wall to wall mapping of biomass (Fatoyinbo. 2012).

Despite the continuous advances in information technology, remote sensing is the only observing platform capable of providing continuous information on biological and physical properties over vast areas of the ocean. Information on this whole range of processes is required for the comprehension of the marine system dynamics. Because the ocean is largely opaque over much of the usable electromagnetic spectrum, the ability of satellites to capture ocean properties is generally confined to the surface. Nevertheless, satellite-borne sensors provide us with a relatively large range of measurements such as sea surface colour, sea surface height, sea surface temperature, sea surface winds, sea surface salinity, waves, and to a lesser extent, current fields.

2. Monitoring of natural disasters and industrial accidents

Analysis of the factors that precede and accompany disasters and accidents.

Possible objectives are:

- monitoring of emergencies associated with natural and anthropogenic impacts
- simulation of emergency situations and prediction of their consequences
- planning of emergency and rescue operations in areas of natural and anthropogenic disasters

Figure 2: Natural Disasters and Industrial Accidents

Among all kinds of natural hazards of the world flood is probably most devastating, wide spread and frequent. Floods resulting from excessive rainfall within a short duration of time and consequent high river discharge damage crops and infrastructures. They also result in siltation of the reservoirs and hence limit the capacity of existing dams to control floods. For formulating any flood management strategy the first step is to identify the area most vulnerable to flooding.

Biomass burning has been a topic of research interest for many years due to the implications for climatic change as a result of landscape alteration and atmospheric loading of aerosols and trace gases from pyrogenic emissions (Fatoyinbo. 2012). Many of the channels available from a particular satellite sensor are useful for fire monitoring, for example aerosols can be monitored using the visible and near-infrared bands or burn scars can be monitored with the visible, near, and middle infrared bands. Burned area mapping, a commonly used metric, is important for estimating total biomass consumed and thus emission estimates.

Coastline mapping and coastline change detection are critical for safe navigation, sustainable coastal resource management and environmental protection. Zhang et al. [2010] developed a modelling methodology for simulation of long-term morphological evolution of the southern Baltic coast approving that the high-resolution process-based models are useful tools in helping for further understanding and quantification of mechanisms driving coastal evolution.

3. Monitoring of technogenic sphere

Diagnosis of the area topography, analysis and evaluation of forms, geometry and partition technogenic objects, the mapping of dangerous or potentially dangerous areas on the basis of different information available, diagnosis of soil corrosives, diagnosis of linearly extended objects with a precise identification of specific nodes and elements, etc.

Possible objectives are:

- identification of the technogenic objects (tanks, industrial buildings, roads, pipelines, power plants, fuel and freight terminals, ports, etc.) and their characteristics
- assessment and diagnosis forms, geometry, size of the object
- identification of potentially dangerous objects
- analysis of the topography of territory nearby the object
- identification and analysis of the pipeline routes
- analysis and evaluation of the dynamics of flooding of the monitored area

Figure 3: Technogenic Objects

There is hundreds of big nuclear energy and chemical enterprises in the world and the accumulated nuclear and chemical stocks are enough to destroy all living beings on earth several times. A chemical accident is a violation of production processes at chemical facilities accompanied by damage to and (or) destruction of pipelines, tanks, storage facilities, or transport means, which result in a release of chemically hazardous substances into the atmosphere or biosphere, endangering biocenosis and the lives and health of people (Menshikov, Perminov, and Urlichich 2012).

4. MAIN MONITORING OBJECTS IN LATVIA

In accordance to the Civil Defence Plan of Latvian Republic (Cabinet of Ministers 2011), following are main risks areas:

- storm, rainwater, snowfall, icing, blizzard;
- water flood;
- forest and turbary fire;
- oil and oil product pipelines;
- gas main and gas regulation stations;

- national and regional high-risk objects that produce, use, manage or store hazardous substances;
- hazardous substances leak;
- nuclear power plants that operates within the 300, 500, and 1000 km from the national boundary.

Water flood is one of the severest natural disasters resulting in heavy economic damage and casualties. Remote sensing techniques allow monitoring of water resources, including the development of hydrological digital model of topography, water basin detection, simulation of a leak direction and speed, verifying water quality and pollution movement (see Fig.4.), mapping of inundated territory during spring flood and overflow, detection of anthropogenic and natural changes of water mass. Based on the monitoring results following information for preventive measures could be collected:

- water level and ice drift in rivers;
- forecast of flooding areas;
- water basin inspection;
- the risk of soil erosion;
- etc.

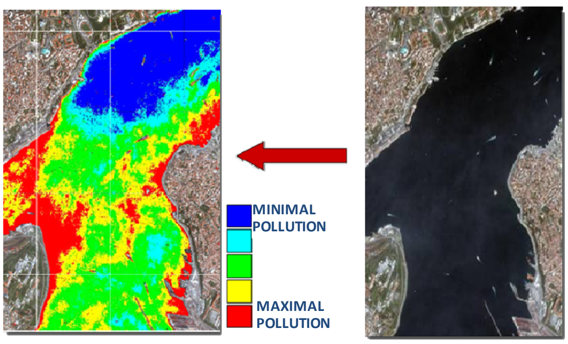

Figure 4: Monitoring of the Water Pollution (Rekod 2012)

Following are information necessary for early detection and liquidation of the disaster consequences:

- determination of the necessary level of water lowering;
- forecasting of the measures on the liquidation of consequences;
- region of antiepidemic action determination;
- dangerous object in the adjacent territory;
- etc.

Forest fires play a critical role in landscape transformation, vegetation succession, soil degradation and air quality (Chuvieco E., Aguado I., Yebra M. et al. 2010). Possibility of fire suppression on a small area, especially in high fire hazard, depends on timely detection and primary fire response (ScanEx 2012). The monitoring of forest fires usually include detection of the thermal anomaly and controlling of the fire propagation. Fire sites can be therewith interpreted both visually and automatically (infrared spectrum), using radiance temperatures of thermal channels. Algorithms of detecting fires in automatic mode are based on a considerable difference in temperatures between the ground surface (usually, not exceeding 10-250C) and the fire spot (300-9000C). Almost a hundredfold difference in thermal radiance of the objects is registered on the images, whereas the information received from the other spectral channels helps to discriminate the clouds.


Figure 5: Visual Imaging of Thermal Anomaly (Rekod 2012)

Following are information necessary for early detection and liquidation of the disaster consequences:

- determination of the fire propagation;
- possible scenarios of population evacuation from dangerous zone;
- forecasting of the possible fire propagation within the protected zone, where railways, gas and oil main is located;
- etc.

As recent events have shown, high-risks objects are facing increasingly complex issues in a continually evolving natural and business environment. Two issues stand out: companies are expected to operate closer to their maximum capacity therefore there is an increased need for accurate and better monitoring of the high-risks objects.

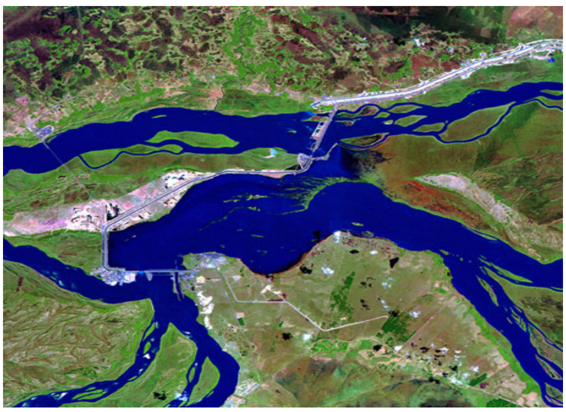
Figure 6: Monitoring of Hydroelectric Power Plant

Many tasks could be addressed to the monitoring issue of the high-risks objects, e.g.:

- controlling of the hydraulic structure condition (see Fig. 6);
- detection of technogenic explosion;

- controlling of hazardous substances propagation (see Fig.7.);
- observing of oil/gas main;
- emergency situation controlling in public services;
- etc.

Based on monitoring results, the following information for preventive measures could be collected:
- inspection of hazardous substances and high-risk object condition (electromagnetic radiation, temperature, amount of pollution, pressure, etc.);
- inspection of smoke covering in habitat areas;
- etc.

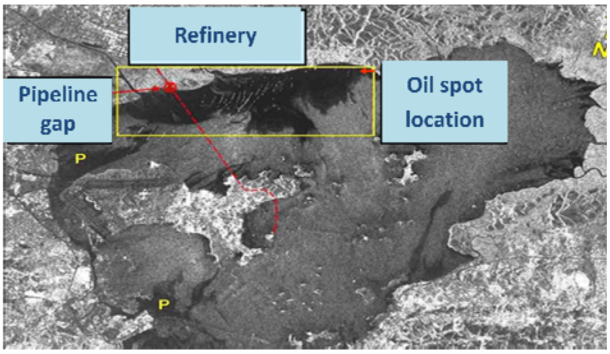

Figure 7: Oil Spill Detection and Monitoring (Rekod 2012)

The necessary information for early detection and liquidation of the disaster consequences are:
- forecasting of the measures on the liquidation of consequences;
- damage evaluation;
- possible scenarios of population evacuation from dangerous zone;
- forecasting of the possible hazardous substances propagation;
- etc.

The above mentioned objects are in a high priority for Latvian Republic to be monitored, therefore the analysis of application of remote sensing technologies for their monitoring is essential.

5. CONCLUSIONS

The monitoring of natural-technogenic objects is focused on the issues of changing ecosystem, geosystem, climate and providing services for sustainable economy, healthy environment and better human life by the following activities:
- Early warning of natural and anthropogenic disasters.
- Technogenic objects security.
- Land cover/land change, natural resource usage.
- Human health and the preservation of the environment.

The paper highlights the most crucial monitoring object in Latvia taking into account natural and business environments, namely water flood, water pollution, forest fires, and high-risk technogenic objects, especially big and small size hydroelectric power plants. The further research is aimed at analysing ground-space technologies and developing of monitoring objects conceptual models to be applied into the integrated intelligent platform developed within the INFROM Project.

ACKNOWLEDGEMENT

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MODELING RICH AND DYNAMIC VEHICLE ROUTING PROBLEMS IN HEURISTICLAB

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ABSTRACT
Transport is one of the largest emission driving forces and has many economic and social impacts. Thus it is crucial to model and optimize practical transportation problems. In this paper we present a flexible modeling and optimization framework integrated in the open source environment HeuristicLab. We show, how rich and dynamic vehicle routing problem variants can be integrated in our framework. Using this model, we perform an algorithmic study where we compare several heuristic and metaheuristic algorithms for the dynamic pickup and delivery problem with time windows.

Keywords: dynamic vehicle routing problem, simulation, optimization

1. INTRODUCTION
According to a recent report by the European Commission and Eurostat (2011), transport caused 19.5% of all greenhouse gas emissions in 2008. The emissions generated by transport grew by 5% between 1999 and 2008 and thus transport is one of the largest emission driving forces. This is explained by increasing transport volumes and a lack of cleaner fuels and modes. As a result, an energy-efficient transport is an important contribution to a sustainable development.

The vehicle routing problem (VRP) is an important problem class in operations research (OR) since it can be used to model many different types of transportation problems. Since its original formulation by Dantzig and Ramser (1959), many variants have emerged and have been successfully applied in practice. For a taxonomic overview of different VRP variants the reader is referred to Eksioglu et al. (2009). A survey on recent advances and challenges in the field of vehicle routing is given by Golden and his colleagues (2008).

Challenges in contemporary vehicle routing research are on the one hand rich models that include many practical side constraints (Hartl et al. 2006) and on the other hand dynamic and stochastic formulations (Zeimpekis et al. 2007, Pillac et al. 2011).

Thus it is crucial to have a flexible software platform that can be applied to various variants of dynamic vehicle routing problems. In this work, we present how rich, dynamic vehicle routing problems are modeled in the open-source platform HeuristicLab (Wagner, 2009).

2. METHODOLOGY
To model dynamic VRPs, a simulation component is required that replaces the real practical environment. It can be used both for algorithm development and scenario evaluation. Thus, the combination of simulation and optimization is a powerful technique in that context.

The overall model is illustrated in Figure 1. The simulation component contains a problem environment that specifies the constraints such as number of vehicles, capacities or the underlying transport network. The simulation model is based on Vonolfen et al. (2010) and has been adapted to dynamic problems.

The problem environment generates orders dynamically which are transportation requests that have to be served by a fleet of vehicles. The vehicles act inside the problem environment and deliver the orders given the constraints.

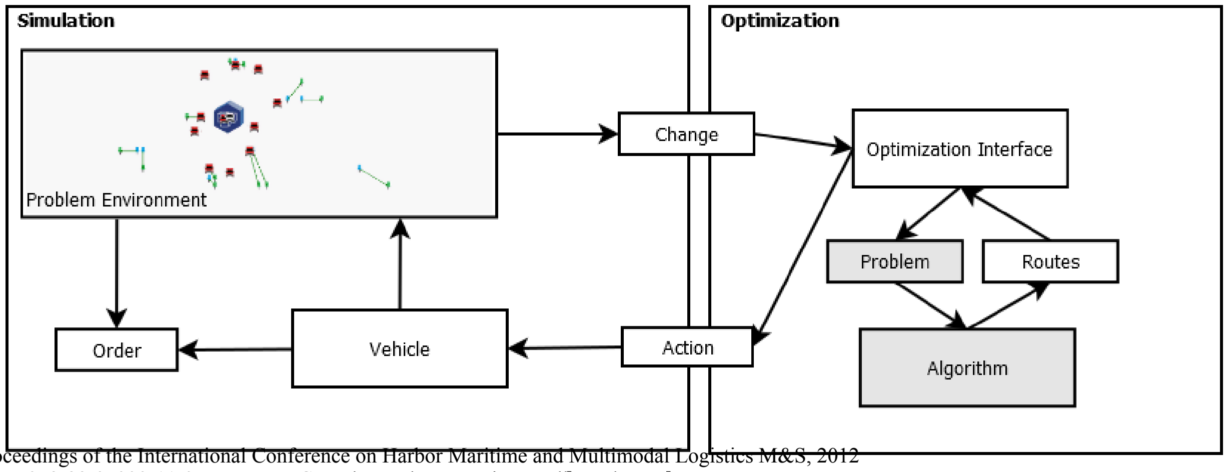

Figure 1: Simulation and Optimization

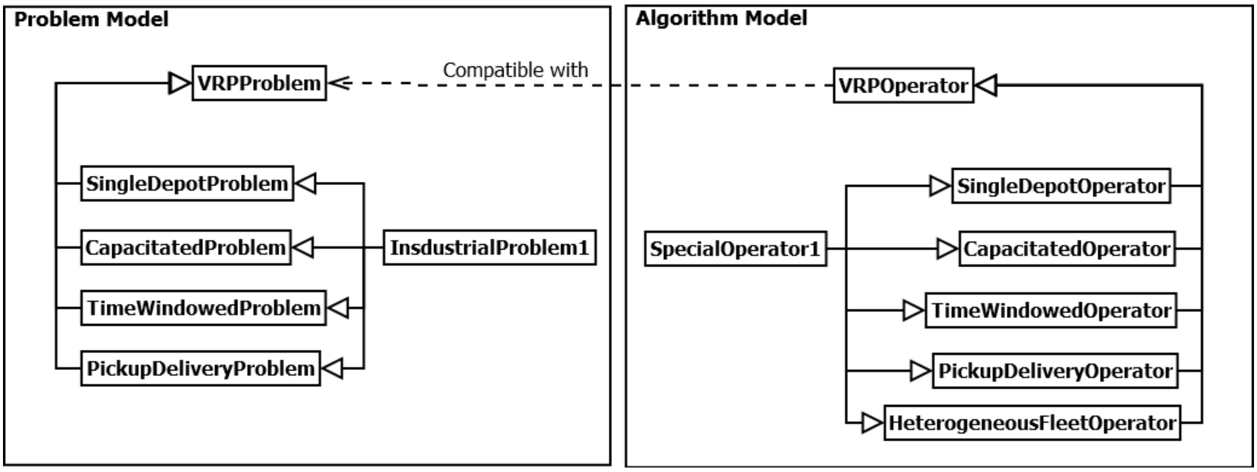

Figure 2: Problem and Algorithm Model

Whenever a dynamic event happens in the problem environment (e.g. an order is delivered, a new order appears or a vehicle breaks down), a change event is triggered and the optimization component is notified. The optimization component reacts to changes and triggers actions that are performed by the vehicles.

Different routing algorithms implemented in HeuristicLab are integrated by the optimization interface. The optimization interface transforms the current situation (including the recent changes) to a problem model and calls the underlying algorithm. The algorithm returns a route plan which is mapped to actions that are performed by the vehicles.

The grey components in the picture (problem and algorithm) have to be adapted to the problem environment and are highly dependent on the side constraints. Thus, a flexible problem and algorithm model is required in HeuristicLab to be able to model diverse rich variants of practical VRPs.

The model is illustrated in Figure 2. Each problem model requires certain side constraints that have to be considered by the algorithm solving it. For instance, practical problems may consist of multiple depots, a heterogeneous fleet or incorporate pickup and delivery operations.

The algorithm is composed of building blocks called operators. The operators offer certain features that can be considered. The algorithm can be modeled in a flexible way. For a certain problem environment, suitable operators can be chosen that can consider the required side constraints. Operators developed for other rich practical VRP variants can be reused in other problem environments.

3. PROBLEM FORMULATION

To illustrate our model, we implemented an example practical VRP variant and tested different algorithms for that problem environment.

In particular, we consider the dynamic pickup and delivery problem with time windows (PDPTW) which can be considered as a rich transportation problem. Practical applications of the dynamic PDPTW are manifold and include full-truckload problems, less-than-truckload problems and passenger transportation.

Its formulation is based on the static PDPTW model (Savelsbergh 1995). A fleet of vehicles has to serve a set transportation requests during a planning period (i.e. a day of operation). Each request is characterized by a pickup and a delivery location and the size of the load to be transported. For each location, a time window is given in which the service has to occur. A request has to be fulfilled by exactly one service of a single vehicle; this means that split deliveries are not allowed. In the dynamic formulation, not all requests are known in advance but are revealed during the planning period.

Dynamic vehicle routing problems are characterized by changing information and the routes evolve regarding to those inputs in real-time (Psaraftis 1988). The focus will be on the arrival of new requests during the planning process. At a certain time instant *t* the route plan is divided into three parts (Ichoua et al. 2007): the completed movements, the current movement and the planned movements.

Early research on dynamic PDP includes Shen et al. (1995) and Potvin et al. (1995) where they apply neural networks with learning capabilities.

In terms of neighborhood based metaheuristics, a tabu search algorithm with a neighborhood elimination matrix was applied by Malca and Semet (2004). Gendreau and Potvin (1998) apply a tabu-search heuristic based on a neighborhood of ejection chains. A two-phase solution approach where a tabu search is combined with different waiting strategies is examined by Mitrovic-Minic and Laporte (2004).

But also population-based metaheuristcs have been applied successfully. A grouping-based genetic algorithm is applied to a set of benchmark instances by Pankratz (2005). A genetic algorithm hybridized with fuzzy clustering for predictive control is presented by Saez et al. (2009).

4. ALGORITHMS

In this work, two different strategies for optimizing dynamic pickup and delivery problems are examined, namely updating of the current plan and complete reoptimization. The first approach corresponds to integrating the new requests in the planned movement while the second approach relies on a complete reoptimization whenever new information is revealed. Both commonly used heuristics as well as metaheuristics are analyzed. The algorithms are detailed in the following.

4.1. Heuristics

A straightforward approach of updating the current route plan according to newly arriving requests is to insert them at the best possible position of the planned routes. This is often referred to as the best insertion heuristic. A major drawback is that decisions made in the past that correspond to planned movements cannot be changed at a later time during the planning process.

This issue can be overcome by a complete reoptimization of the planned routes at each time step *t* given the current situation. This can be done for instance by means of a construction heuristics. A push forward insertion heuristic is examined which has been originally proposed by Solomon (1987) for the vehicle routing problem with time windows (VRPTW). It has been adapted to the PDPTW by Li and Lim (2001). It basically inserts pairs of locations into routes. A pair of locations consists of a pickup and a delivery location. First a route is initialized with a pair based on the distance to depot and time windows. Then iteratively a pair that causes the minimum insertion costs is inserted into the route until no pair can be feasibly inserted. Then a new tour is started. This procedure is repeated until all pairs of customers are routed.

4.2. Metaheuristics

Two metaheuristics for the optimization of dynamic pickup and delivery problems are compared, namely a genetic algorithm and tabu search. Those two algorithms have been used frequently for the PDPTW in the literature. In terms of parameter setting, a single set of parameters has been tested which has been determined empirically.

The applied genetic algorithm uses mutation and crossover operators proposed by Potvin and Bengio (1996); i.e. the one-level exchange mutator, two-level exchange mutator, route-based crossover and sequence-based crossover. They are implemented using a route-based encoding which is examined and compared with other encodings by Vonolfen et al. (2012). The initial generation is obtained by using the before mentioned push forward insertion heuristic. In terms of algorithm parameters, a population size of 50 is used with a tournament selection and a mutation probability of 5%. Whenever a new request arrives, the algorithm is given 100 generations to compute a new route plan.

The tabu search algorithm utilizes three different neighborhoods that have been proposed by Li and Lim (2001). The shift neighborhood considers moves where pickup and delivery customer pairs are shifted from one route to another. In the exchange neighborhood pairs are swapped between two routes. Within one route pairs can be moved to another position in the rearrange neighborhood. In each iteration, 1000 possible moves are sampled from the neighborhoods. To achieve that, 10 different neighborhoods and from each neighborhood 100 moves are sampled uniformly. As a tabu criterion, a customer cannot be moved back to a route once it has been removed or rearranged in it. A tabu tenure of 10 is used with a soft aspiration criterion for improving moves. The soft aspiration criterion accepts both new best solutions and moves that are better than the individual where the move has been set tabu. A fixed tabu tenure has been used because all tested instances consist of the same number of customers. At the arrival of a new request, 100 iterations are performed.

Whenever a new request arrives, there are two approaches in integrating it in the current route plan (Ichoua et al. 2007). The first approach is a complete reoptimization, the second approach is a local update whenever new information is revealed. In the local update approach, the route plan is not computed from scratch but information about previous time steps is used. In the case of the genetic algorithm, whenever a new request arrives it is inserted into each individual of the population using the best insertion heuristic. For the local update tabu search algorithm, the current solution and the tabu list are updated.

5. EXPERIMENTS

To evaluate the performance of the algorithms, test runs have been performed on various benchmark instances. The goal is to minimize both the required fleet and the driven distance. The test instances have been retrieved from the benchmark data set proposed by Pankratz (2005). It includes several different dynamic PDPTW instances with various properties. This means that all requests are dynamic and occur during the planning process.

The test set contains different instance types, which are the C1, C2, R1, R2, RC1 and RC2 types with different urgency factors. This sums up to a total of 12 instance classes. The C instances contain geographically clustered, the R instances randomly distributed and the RC instances both clustered and randomly distributed customers. The instances with a "1" as a suffix contain customers with large time windows as opposed to the instances with a "2" which are characterized by tight time windows. Each class contains 8-12 different instances.

All instances are based on the well-known Solomon benchmark set (http://web.cba.neu.edu/~msolomon/problems.htm). All instances consist of 100 customers making up a total of 50 dynamic requests. The best known results for the offline instances are listed in Table 1 and have been retrieved from the SINTEF website (http://www.sintef.no/Projectweb/TOP/Problems/VRPTW/Solomon-benchmark/100-customers).

Problem	Vehicles	Distance
C1	10,00	828,38
C2	3,00	589,86
R1	11,92	1209,89
R2	2,73	951,02
RC1	11,50	1384,16
RC2	3,25	1119,17

Table 1: Best Known Results for the Offline Instances

Based on these static instances, the test set contains different instance classes in terms of degree of dynamism. For the purpose of this paper, instance classes with no a-priori knowledge have been chosen. The instances have different urgency factors, namely 10% and 90%. The urgency factor determines how long in advance the request is known in relation to the latest service time and thus how long the reaction time is. The heterogeneity of the test instances allows us an algorithm performance analysis under different dynamic, spatial and temporal properties.

The dynamically arriving customers are determined beforehand and the same instances are used for all algorithms. Multiple runs are required to capture the stochastic behavior of the algorithms. For the best insertion heuristic only one single run was required, since it is deterministic.

For all other algorithms, three independent test runs have been performed on each instance and the average results in terms of fleet size (vehicles) and distance are listed.

The examined algorithms include both heuristics (best insertion, push forward insertion) and metaheuristics (reoptimization genetic algorithm, local update genetic algorithm, reoptimization tabu search, local update tabu search). They are described in the previous Section.

		Best Insertion		PF Insertion	
Urg.	Class	Vehicles	Distance	Vehicles	Distance
10%	C1	11.44	1618.88	12.56	1308.14
	C2	4	1391.61	4.63	1209.47
	R1	16.33	1785.75	17.33	1704.87
	R2	4.3	1779.31	4.7	1755.94
	RC1	17.5	2199.07	17.88	2017.66
	RC2	5.13	2149.45	6	2246.08
90%	C1	20.22	1926.49	19.78	1682.96
	C2	9.5	2291.86	9.63	1992.82
	R1	24.81	2160.19	25.27	2126.19
	R2	9.83	2508.69	10.38	2280.97
	RC1	27	2688.08	27.25	2631.74
	RC2	10.13	2818.12	10.75	2692.01

Table 2: Results for the Heuristics

The results achieved by using heuristics are summarized in Table 2. The push forward insertion heuristic generally outperforms the best insertion heuristic in terms of distance.

This can be explained by the fact that reoptimizing the routes in each time step leaves a larger room for optimization potential than gradually inserting newly arriving requests where existing plans cannot be changed. However, the push forward insertion heuristic uses a larger fleet size on average, which indicates that the parameters could be tuned to use fewer vehicles.

The results achieved by the metaheuristics are listed in Table 3. The local update tabu search is the best performing algorithm both in terms of fleet size and in terms of distance. This indicates that it can adapt the existing plan efficiently to newly arriving requests.

		Reopt. GA		Local Update GA		Reopt. TS		Local Update TS	
Urg.	Class	Vehicles	Distance	Vehicles	Distance	Vehicles	Distance	Vehicles	Distance
10%	C1	10.78	960.61	10.52	1113.3	11.33	938.93	10.52	962.44
	C2	3.92	712.73	3.67	746.14	4.08	774.04	3.75	718.87
	R1	15	1465.63	14.28	1474.89	16.19	1445.82	14.22	1404.11
	R2	3.87	1329.18	3.6	1266.52	4.9	1277.67	3.33	1160.53
	RC1	16.13	1762.6	14.92	1763.5	16.96	1735.95	14.13	1643.9
	RC2	4.67	1530.99	4.04	1463.45	5.25	1500.95	4.08	1350.67
90%	C1	19.44	1672.09	20.19	1756.41	19.48	1658.73	19.44	1638.31
	C2	8.58	1514.82	9.42	1591.36	8.63	1490.47	8.63	1528.09
	R1	23.92	2068.52	24.32	2090.12	23.46	2036.24	23.57	2036.08
	R2	8.86	2036.18	9.59	2107.94	8.55	2000.1	8.62	2020.9
	RC1	26.67	2602.16	26.71	2601.37	26.25	2566.1	26.25	2562.46
	RC2	9.25	2380.12	9.92	2479.97	9.33	2374.48	9.25	2362.02

Table 3: Results for the Metaheuristics

A summary of the conducted experiments is illustrated in Figure 3. All metaheuristic algorithms can outperform the heuristics significantly both in terms of distance and in terms of fleet size. However, it can also be observed that the performance of the algorithms decreases significantly with increasing urgency.

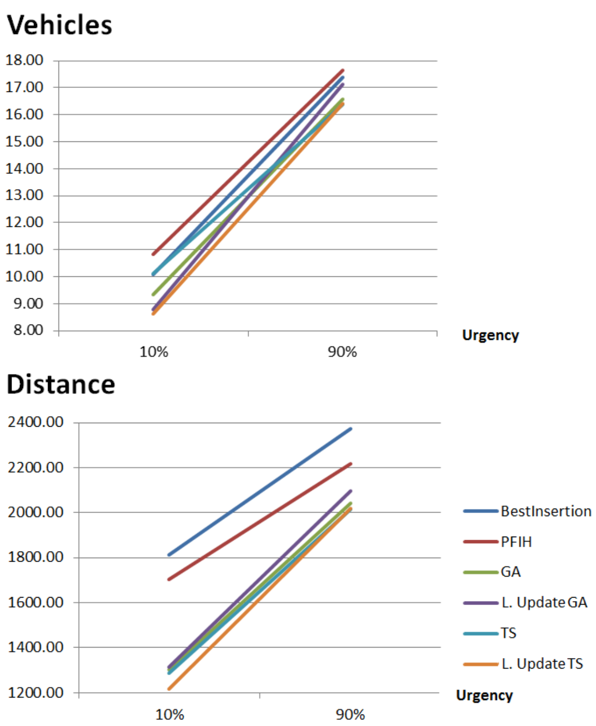

Figure 3: Summary of the Results

This shows that adapting well performing static algorithms is not sufficient for highly dynamic problems. The algorithmic concepts have to be extended by a mechanism to anticipate future requests such as waiting strategies with a double horizon approach (Mitrovic-Minic and Laporte 2004) or a scenario based technique (Van Hentenryck and Bent 2009). However, according to Berbeglia et al. (2010), the literature is still very scarce in terms of dynamic and stochastic PDP.

Work on dynamic and stochastic vehicle routing problems includes Van Hentenryck and Bent (2004), Hvattum et al. (2006) and Secomandi and Margot

(2009). The most promising approach seems to be the multi-plan approach of Van Hentenryck and Bent (2004) which shows large improvements compared to approaches that do not use information regarding customer order probabilities.

6. CONCLUSION

We have presented a flexible and extensible model for rich and dynamic vehicle routing problems. The model is incorporated in the open-source optimization framework HeuristicLab. To illustrate our approach, we have implemented an example dynamic transportation problem and evaluated the performance of different optimization algorithms.

In future work, we want to extend our problem models with stochastic aspects to anticipate future requests. Possible extensions include waiting strategies, multi-plan approaches and double-horizon approaches.

Also, the framework will be used in practical projects involving company partners to model rich transportation problems and to adapt the algorithms to the specific environments.

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INFORMATION FUSION MULTIPLE-MODELS QUALITY DEFINITION AND ESTIMATION

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ABSTRACT
Nowadays the theory, methods and techniques concerning the application of mathematical models are wide used. Nevertheless such problems as a quality estimation of multi-criteria models, an analysis and classification of applied models, as well as justified selection of task-oriented models are still not well investigated. The importance of the problem increases when a research object is described not via a single model, but with a set or a complex of multiple-models including models from different classes or combined models such as combined analytical–simulation models, logical-algebraic ones, etc. Aforementioned problems are the primary research objects of the quality control theory of mathematical models and multiple-model complexes. The description of main elements of this theory is the primary goal of the paper. The implementation of this theory is connected with the information fusion multiple-models area

Keywords: multiple-model descripion and estimation, analysis and classificationt of models, justified selection of applied task-oriented models, quality control of model complexes.

1. INTRODUCTION

One of the most important factors of scientific and technological revolution is the introduction of automatic systems and informational systems (AS and IS) in all fields of human activity (Yusupov and Zabolotskii 2000). Both in the field of industrial manufacturing and in the informational sphere, the role and significance of such a notion as quality is constantly growing and is being developed under the influence of novel technologies and market needs. In the last decades, the problems connected with testing the quality of products have become the subject of intensive investigations conducted in such a new scientific branch as quality science. One of the main branches of this science is qualimetry, which is devoted to the development of methodological backgrounds for the quantitative estimation of product quality (Azgal'dov 1982).

The central concept of both quality science and qualimetry is the concept of quality, which, according to the ISO 8402-2000 international standard, means a totality of characteristics of an object that determine its capability to satisfy the established or supposed requirements (Azgal'dov 1982; Andrianov and Subetto 1990). In the field of designing and applying new information technologies, the investigations devoted to estimation of the product quality have been long conducted. The results of these investigations have been reflected in the international standards and our GOST (Lipaev 2001). For example, the international standard ISO 9126:1991 "Information technology. Evaluation of software products. Quality characteristics and a manual for their application" (Lipaev 2001; International Standards ISO 9000 and 10000 for the Quality System: Versions of 1994 1995) and the subsequent standards (ISO 9126:1--4, ISO 14598-1--6: 1998--2000) contain models, indices, criteria, and metrics of the quality of software tools and products (Lipaev 2001).

The analysis of the results obtained in this field has shown that, by now, there exist methodological tools that allow one to evaluate the quality of a computer model or a computer program (Lipaev 2001; International Standards ISO 9000 and 10000 for the Quality System: Versions of 1994 1995). Therefore, in the modern conditions, the development of tools for evaluating the quality of methods, models, algorithms, and methodologies at earlier stages of modeling original objects is very topical.

It is worth noting that, in the field of investigating the quality of models, many scientific and practical results connected both with qualitative and quantitative estimation and analysis of the properties of models (Samarskii and Mikhailov 2001; Merkuryeva, Merkuryev and Vanmaele 2011) and the choice (synthesis) of models have already been obtained (Krishans, Mutule, Merkuryev and Oleinikova 2011; Savin 2000; Prangishvili 2000). For different application domains, specific theories and technologies of modeling have been designed. In addition, a large number of bases of models and poly-model systems have been developed which are being widely used in practical investigations (Aframchuk, Vavilov, Emel'yanov et al**.** 1998; Ivanov and Sokolov 2010; Vasil'ev 2001; Sethi and Thompson 2006).

Together with this, under the presence of a large number of various models, the problems of substantiated choice of models, their comparison, arrangement, and comparison of different technologies of modeling are still unsolved (Aframchuk, Vavilov, Emel'yanov et al**.** 1998).

Moreover, under the modern conditions, there is an urgent need in designing information technologies that can be used without designers as free as it can be done for the corresponding software products (Val'kman 1996). First of all, to solve all specified problems, the theoretical backgrounds that allow one to solve problems of evaluating and analyzing the quality of models and poly-model (multiple-model) systems have to be developed. The results of this investigation are very important for substantiation choice of structure of multiple-model complexes in different areas. In our case we use these results for structure-functional synthesis of multimodal interfaces in man-machine systems (Krishans, Mutule, Merkuryev and Oleinikova 2011; Savin 2000; Prangishvili 2000; Aframchuk, Vavilov, Emel'yanov, et al**.**, 1998; Ivanov and Sokolov 2010; Vasil'ev 2001; Sethi and Thompson 2006; Val'kman 1996; Pavlovskii 2000). The main problem of these systems is connected with information fusions from different types of input devices (an eye-gaze, a gaze-speech, a manual-gaze-speech input devices, for example). In our paper we propose the methodological backgrounds of the solution of the problem of qualimetry of models employed in integration of data and knowledge from multi-model interfaces in man-machine systems.

2. THE MAIN TASKS AND RESULTS OF INVESTIGATION

2.1. Problem A. Investigation overview and related work

The analysis of the material presented above has shown that, regrettably, in modern conditions, the problems of estimating the quality of models, analyzing, ranking their classes, reliably synthesizing new models, or choosing existing models that are preferable for solving particular applied problems are still unsolved. The topicality of this problem grows when the investigated object is described by a poly-model system, which may contain diverse and combined structures estimated by their own indices (Aframchuk, Vavilov, Emel'yanov et al**.** 1998; Sethi and Thompson 2006; Pavlovskii 2000; Moiseev 1981; Tyatyushkin 2003). Additional complexity arises when we should take into account the *time factor*. This is mainly true for original objects that, due to some reasons (objective, subjective, internal, external, etc.), have structural dynamics (Okhtilev, Sokolov, Yusupov 2006). Under these conditions, to provide that a model preserves its adequacy, it is necessary to adapt its parameters and structures to changeable conditions. For this purpose, in advance, at the stage of synthesizing the model, it is necessary to introduce in the composition of its parameters and structures additional elements (redundancy). In the further application, these elements will allow one to control the model quality and to reduce the sensitivity of the model and the corresponding quality indices to variations in the composition, structure, and content of the source data. However, in our opinion, to constructively solve the general problem of evaluating and controlling the quality of models (of choosing the most preferable variants), first of all, we should investigate the following complexes of problems: *to describe, classify, and choose a system of indices that evaluates the quality of models and poly-model systems; to develop a generalized description (macrodescription) of various classes of models (macromodels) that allow one, first, to establish interrelations and correspondences between the types and kinds of models, and, second, to compare and rank them, using various metrics; to develop combined methods for estimating quality indices of models (poly-model systems) given by numerical and non-numerical (nominal and ordinal) scales; to develop methods and algorithms for solving problems of multicriterial analysis, ordering, choice of the most preferable models (poly-model systems), and control of their quality; and to develop the methodological backgrounds of the solutions of problems of multicriterial analysis and synthesis of technologies of integrated (system) modeling of complex objects.*

In our opinion, the specified problems and the methodological backgrounds for their solution, supplemented by the development of the conceptual and methodological base, can be regarded as components of a new applied theory, which will be called in what follows *qualimetry of models (modelmetry)* (Okhtilev, Sokolov, Yusupov 2006). Consider in detail the most important aspects of the specified problems of qualimetry of models and poly-model systems.

The concept of model is widely applicable in natural human languages and is a general scientific term. It is characterized by polysemy that is brightly expressed and reflects different meanings of this concept depending on applications and contexts. At present, there are several hundred definitions of the concept of a model and modeling (Peregudov and Tarrasenko 1989). Let us present some of them (Samarskii and Mikhailov 2001; Sethi and Thompson 2006; Pavlovskii 2000; *Reliability and Efficiency in Engineering: Handbook* 1988; Rostovtsev Yu.G. and Yusupov R.M. 1991). For example, a model is a system whose investigation is a tool for obtaining information about another system; a model is a method of knowledge existence; a model is a multiple-system map of the original object that, together with absolutely true content, contains conditionally true and false content, which reveals itself in the process of its creation and practical use; modeling is one of the stages of cognitive activity of a subject, involving the development (choice) of a model, conduction of investigations with its help, obtaining and analyzing the results, production of recommendations on the further activity of the subject, and estimation of the quality of the model itself as applied to the solved problem and taking into account specific conditions.

The analysis of the listed definitions implies that each correctly designed model contains objective truth (i.e., to some extent, it correctly reflects the original object) (Peregudov and Tarrasenko 1989; *Reliability and Efficiency in Engineering: Handbook* 1988). Together with this, because of the finiteness of the designed (applied) model (a limited number of elements and relations that describe objects belonging to infinitely diverse reality) and limited resources (temporal, financial, and material) supplied for modeling, the model always reflects the original object in a simplified and approximate way. However, the human experience testifies that these specific features of a model are admissible and do not oppose the solution of problems that are faced by subjects. In the course of modeling, it is advisable to distinguish the following basic elements and relations: first, a subject or subjects $(S^{m}_{<>})$, an original object $(Ob^{op}_{<>})$, model-object $(Ob^{m}_{<>})$, an environment $(CP^{m}_{<>})$ in which the modeling is performed; and, second, binary relations between the listed elements $R_{<1>}(Ob^{op}_{<>}, S^{m}_{<>})$, $R_{<2>}(S^{m}_{<>}, Ob^{m}_{<>})$, $R_{<3>}(Ob^{op}_{<>}, Ob^{m}_{<>})$, $R_{<4>}(CP^{m}_{<>}, Ob^{op}_{<>})$, $R_{<5>}(CP^{m}_{<>}, Ob^{m}_{<>})$, and $R_{<6>}(CP^{m}_{<>}, S^{m}_{<>})$. The subscripts $"<>"$ mean the personal names of objects (subjects) and relations (Rostovtsev and Yusupov 1991). Note that, in what follows, subjects of modeling mean the following classes of social subjects: decision makers (DM); persons that substantiate the decisions (PSD); experts; persons that use the models; and persons who design the models. Figure 1 presents possible variants of the interrelation between the listed elements and relations between them.

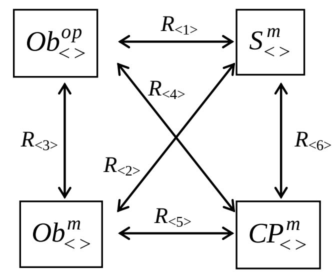

Figure 1: All possible interrelations of objects and subjects of modeling

It is worth noting that one of the main specific features of original objects (real or abstract) is their exceptional complexity (Prangishvili 2000; Aframchuk, Vavilov, Emel'yanov et al**.** 1998) that reveals itself in the form of *structural complexity*, *complexity of functioning, complexity of the choice of behavior*, and *complexity of development*. Therefore, to describe such objects, we should use several models, rather than a unique model. In other words, we should perform *system modeling* (polymodel description of the application domain) (Aframchuk, Vavilov, Emel'yanov et al**.** 1998). Another specific feature of the modern stage of development of methods and tools of abstract modeling consists in considerable intensification of works in automation of this process and, first of all, the phase connected with the design of a computer model (Krishans, Mutule, Merkuryev and Oleinikova 2011; Aframchuk, Vavilov, Emel'yanov et al**.** 1998; Sethi and Thompson 2006). Moreover, within the framework of new information technologies based on the concepts of knowledge bases, the concept of "model" has considerably extended the limits of its application - from the field of passive informational resources to the field of active ones. Under these conditions, algorithms that are elements of procedural knowledge turn into operating environments that provide the solution of problems by a subject in the language of models. The most important components of the conceptual base of qualimetry of models and poly-model systems are their properties. Therefore, we briefly describe the main properties of models that should first be evaluated in their comparison and choice.

1. *Adequacy* (from Latin *adaequatus*, which means equated, completely suitable, or comparable). The model should possess the specified property relative to certain aspects of the original object. It is obvious that, in practice, we should say about adequacy in some sense, rather than about complete adequacy. As was mentioned above, for complex systems (original objects), a single model may reflect a side or an aspect of the prototype. Therefore, the concept of adequacy does not exist in general. We may say only about the adequacy of reflection of certain properties. For a poly-model system, we can pose the problem of achievement of adequacy in a broader sense that encompasses various features of the prototype. However, in all cases, the adequacy of the model (poly-model system) should be evaluated taking into account the degree to which it satisfies the goal of modeling (goals of the subject).

We distinguish *qualitative adequacy*, i.e., the reflection of certain qualitative properties of the original object with the help of the model, and *quantitative adequacy*, which means the reproduction of numerical characteristics of the prototype with certain accuracy. For this purpose, various types of metrics are introduced (Ivanov, Sokolov and Kaeschel 2010; Aven, Oslon and Muchnik 1988).

Because of particular significance of this property of models and poly-model systems in the general structure of the generated conceptual base of qualimetry of models, we consider in more detail possible approaches to the quantitative estimation of these characteristics in Section 4. Let us consider other indices.

2. *Simplicity and optimality of the model (poly-model system).* The property of adequacy is directly associated with the properties of simplicity and optimality of the model. Indeed, sometimes, to achieve the required degree of adequacy, we should essentially complicate the model. On the other hand, if we can choose different models that have approximately the same adequacy, it is advisable to use the simplest model. This property becomes very topical under optimal choice of the structure of a poly-model system. In this case, the adequacy of modeling is determined by not only the properties of each model, but also the characteristics of their interaction. In (Peschel 1981, 1978; Polyak 1971), which are devoted to the general theory of modeling complex systems, a number of principles, rules, and methods that provide the correct transition from a formal description $Ob^{op}_{<>}$ to the scheme of modeling (computer program) are found.

3. *The flexibility (adaptability) of models* assumes that parameters and structures that can vary in given ranges are introduced in the composition of models in order to achieve the goals of modeling.

4. *Universality and task orientation of models.* Numerous investigations directed to the search for the specified compromise have shown that, at present, the development of universal models $Ob^{op}_{<>}$ directed to a broad application domain result in a difficult-to-solve problem. It is advisable to design models specialized relative to an admissible class of modeled objects and universal with respect to a list of supported functions.

Among other properties of models, which have to first be investigated in the framework of qualimetry, we should distinguish reliability, unification, simplicity, openness and accessibility, intelligence, the efficiency of computer implementation, complexity, identifiability, stability, sensibility, observability of models, their invariance, and self-organization and self-learning (Aframchuk, Vavilov, Emel'yanov et al**.** 1998; Kalinin, Sokolov 1985).

It was mentioned above that different properties of models that describe original objects $Ob^{op}_{<>}$ are evaluated and analyzed in the course of system modeling (Figure 2), which is one of the types of purposeful processes (*Reliability and Efficiency in Engineering: Handbook* 1988). Therefore, within the framework of qualimetry of models, it is advisable to consider two particular lines of investigation that encompass both the problems of estimating and analyzing the quality of different techniques of modeling $Ob^{op}_{<>}$ and the problems of choosing variants of their optimal organization. Figure 2 presents a typical aggregative technique for conducting system (integrated) modeling as an example (Aframchuk, Vavilov, Emel'yanov et al**.** 1998). In this figure, the following notation is accepted: 1, for theoretical investigations; 2, for methods of structural and behavior analysis; 3, for analytical investigations of models, 4, for designing models (poly-model systems); 5, for development of a modeling algorithm; 6, for designing a computer model; 7, for simulation investigations; and 8, for the representation and interactive analysis of the results of modeling. As applied to different types of $Ob^{op}_{<>}$ different classes of employed models, this scheme may be considerably complicated. For example, in the solution of problems of synthesizing the structures of complex $Ob^{op}_{<>}$, at present, analytical and simulation models that describe various aspects of the specified problems in necessary details are widely applicable (Tsvirkun and Akinfiev 1993). In so doing, several scenarios (procedures and techniques) may be proposed for arranging and conducting integrated modeling, which may be different in the methods of generating admissible alternative solutions, in the rules for testing constraints given in an analytical or algorithmic form, and in the methods of transition from one step of interactive restriction of the set of admissible alternatives to another.

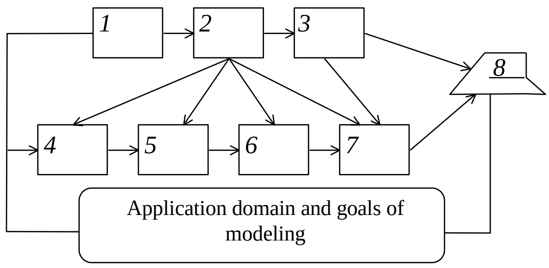

Figure 2: The technology of system modeling

The analysis of results of numerous investigations has shown that joint use of diverse models in the framework of multiple-model systems allows one to improve the flexibility and adaptability of the simulation system (SS), as well as to compensate the drawbacks of one class of models by the advantages of the other (Aframchuk, Vavilov, Emel'yanov et al**.** 1998; Sethi and Thompson 2006; *Reliability and Efficiency in Engineering: Handbook* 1988; Tsvirkun and Akinfiev 1993). Moreover, investigating problems of analyzing and synthesizing the structures $Ob^{op}_{<>}$ in the framework of each of the listed classes of models, the subjects of modeling may use simultaneously and in parallel several methods and algorithms different in computational complexity (*International Standards ISO 9000 and 10000 for the Quality System: Versions of 1994* 1995; Savin 2000; Aframchuk, Vavilov, Emel'yanov et al**.** 1998).

On the whole, each variant of implementation of the technique of system modeling is characterized by its own time cost, the expenditure of different types of resources, and by final results (effects). In these conditions, the problems of evaluating and choosing the best variants are of great interest (*Reliability and Efficiency in Engineering: Handbook* 1988).

2.2. Problem B. The results of investigations

In the solution of problems of modeling of complex objects $Ob^{op}_{<>}$, the problems of providing a required adequacy of the results and controlling the quality of models and the modeling processes is of special importance. It is obvious that, using the model $Ob^{m}_{<>}$ in practical investigations, we should evaluate its adequacy each time relative to $Ob^{op}_{<>}$. The reasons for inadequacy may be inexact source prerequisites in determining the type and structure of the models, measurement errors in testing, computational errors in processing sensor data, etc. (Yusupov 1977). The use of inadequate models may result in considerable economic loss, emergency situations, and failure to execute tasks posed for a real system.

For definiteness, following (Kalinin, Sokolov 1985; Rostovtsev and Yusupov 1991), we consider two classes of modeled systems. By the *first class*, we refer to those systems with which it is possible to conduct experiments and to obtain the values of some characteristics by measuring.

Figure 3 presents the generalized technique for estimating and controlling the quality of models of objects of the first class.

In this figure, we take the following notation: 1, for forming the goals of functioning of $Ob^{op}_{<>}$; 2, for determination of input actions; 3, for setting goals of modeling; 4, for the modeled system (objects $Ob^{op}_{<>}$) of the first class; 5, for the model ($Ob^{m}_{<\theta>}$) of the investigated system $Ob^{op}_{<>}$; 6, for the estimation of the quality of a model (poly-model system); 7, for controlling the quality of models; 8, for controlling the parameters of models; 9, for controlling the structures of models; and 10, for changing the concept of model description.

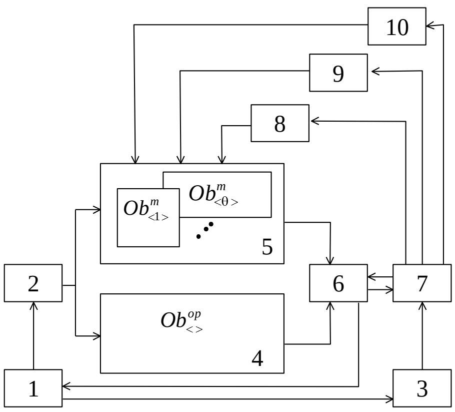

Figure 3: The generalized technique of estimation and control of the quality of models of the first class

All technical systems and complexes working in an autonomous mode are examples of systems of the first class.

We refer to the *second class* of modeled systems, for which it is impossible to conduct experiments (according to the technique presented in Figure 3 and to receive the required characteristics. Large-scale economic and social systems and complex technical systems that function under essential uncertainty of the effect of the external environment are examples of these systems. The human factor plays an important role in these systems (organization structures).

Consider the variants of evaluating the adequacy of $Ob^{m}_{<>}$ for the mentioned systems. We assume that we have a metric space of mathematical patterns that describes $Ob^{op}_{<>}$ and $Ob^{m}_{<>}$. Then, it is advisable to use the distance $\rho(Ob^{op}_{<>}, Ob^{m}_{<>})$ that has to satisfy the axioms of a metric (Yusupov 1977) as the proximity measure between the object and model. In the ideal situation, the proximity measure must be zero. However, in practical cases, because of a number of reasons (the principal difference between $Ob^{m}_{<>}$ and $Ob^{op}_{<>}$), the uncertainty of source data, measurement and computational errors, etc.), the probability of the equality

$$\rho(Ob^{op}_{<>}, Ob^{m}_{<>}) = 0$$

is close to zero. Therefore, a real adequacy condition must have the form

$$\rho(Ob^{op}_{<>}, Ob^{m}_{<>}) \le \varepsilon, \quad \varepsilon > 0\,.$$

The first condition, which has a purely theoretical value, is called the condition of absolute adequacy, and the second one is called ε-adequacy. We also note that, in the course of implementation of one or another technique of modeling (Figures 1, 2, and 3), as a rule, the degree ρ of adequacy decreases in the transition from one stage of modeling to another

$$\rho_1 \le \rho_2 \le \rho_3 ... \rho_{\mathrm{R}} = \rho\,,$$

where ρ_{R} is the adequacy measure of $Ob^{m}_{<>}$ at the *k* stage.

As applied to the first class of $Ob^{op}_{<>}$, the considered adequacy measures can be given in various forms. For example, in deterministic description of systems, the Euclidean metric, Chebyshev metric, Hamming metric, Lee metric, etc., are most frequently used (Yusupov 1977). The value of the difference of the output actions obtained in the object $(\mathbf{y}^{(0)}(t))$ and model $(\mathbf{e} = \mathbf{y}^{(0)}(t) - \mathbf{y}(t))$ is considered as the argument in the corresponding functionals. In the stochastic case, adequacy measures based on the quantitative estimation of the distance between random samples (the first situation) obtained in the course of experiments with $Ob^{op}_{<>}$ and $Ob^{m}_{<>}$ and on the estimation of the distance between the statistical laws constructed based on these samples (the second situation) (Yusupov 1977) can be proposed. In addition to the mentioned approaches in giving metrics for the first situation, the set of other metrics for analytical-simulation, logical-algebraic, logical-linguistic, and combines models have recently been developed (Ivanov, Sokolov and Kaeschel 2010; Aven, Oslon and Muchnik 1988; Yusupov 1977).

The quantitative estimation of the adequacy of models $Ob^{m}_{<>}$ that describe systems of the second class is difficult with the use of the metrics proposed above, since, first, it requires very large resource expenditure in order to directly determine the characteristics of the form $\mathbf{y}^{(0)}$ by conducting experiments with the specified systems, and, second, in a number of situations, it is simply unrealizable (modeling of accidents, catastrophes, and military operations). Moreover, the concept of "model adequacy" itself needs to be refined. In this case, it is advisable to comment on the usefulness and fitness of the model $Ob^{m}_{<>}$ for solving a certain class of problems connected with $Ob^{op}_{<>}$ (Yusupov 1977; Larichev 2000; Ceany and Raiffa 1981; *Fuzzy Sets in Models of Control and Artificial Intelligence* 1986). We assume that, to describe a certain system of the second class $Ob^{op}_{<>}$, k models $M_1(\Gamma_{<p_1>})$, $M_2(\Gamma_{<p_2>})$,..., $M_k(\Gamma_{<p_k>})$ were proposed, each of which is characterized by its structure and a set of parameters $\Gamma_{j<p_j>}$, $j = 1,...,k$. First, we consider the situation when the structures of models are fixed and models differ from each other by the composition of parameters whose exact values are, as a rule, not known. It is necessary to choose the most preferable model among the set of models $\{M_j(\Gamma_{<p_j>})\}$ (Yusupov 1977). In addition, we assume that the listed models are used in order to solve the problems of prediction and choice of optimal variants of functioning of the system $Ob^{op}_{<>}$ from the point of view of a given generalized efficiency index J. Assume that it is not known in advance what actual values are taken by the parameters of a real system. Thus, it is necessary to collect data about the actual behavior of the system $Ob^{op}_{<>}$ under uncertainty conditions. Consequently, we should use additional information.

Consider the simplest situation, when $Ob^{m}_{<>}$ depends only on a single parameter p, which takes a finite number of values, $p \in \{p_1, p_2, ..., p_b\}$. Note that the result of functioning the real system $Ob^{op}_{<>}$ depends on the same parameter, which takes the same values. However, it is not known in advance which actual value is taken by the parameter p in the system $Ob^{op}_{<>}$. Assume that any deviation of the parameter of the model $M_j(p_j)$ from the value of this parameter in the real object results in a "loss," which is estimated by the index J.

To solve the problem, we form Table 1, which contains the values of the efficiency index of the following form: $J_{\nu\mu} = J_{\nu\mu}(u_\nu, p_\mu)$, where $J_{\nu\mu}$ is the value of the index of u_ν for the variant of functioning of $Ob^{op}_{<>}$ computed for the model $M_\nu(p_\nu)$ under the actual value of the parameter p_μ. Based on table 1, we construct table 2 of risks calculated by the formula $\Delta J_{\nu\mu} = | J_{\nu\nu} - J_{\nu\mu}|$.

In this case, the choice of the fittest model is reduced to a choice of a value of p. As an optimization criterion, we take the criterion of minimum risk

$$J' = \min_{\nu} \max_{\mu} \Delta J_{\nu\mu}$$

Table 1: The values of the efficiency indices of the form $J_{\nu\mu} = J_{\nu\mu}(u_\nu, p_\mu)$

	p_μ			
p_ν	p_1	p_2	...	p_b
p_1	J_{11}	J_{12}	...	J_{1b}
p_2	J_{21}	J_{22}	...	J_{2b}
...	...	...	...	...
p_b	J_{b1}	J_{b2}	...	J_{bb}

Table 2: The values of the risks of the form $\Delta J_{\nu\mu} = | J_{\nu\nu} - J_{\nu\mu}|$

	p_μ			
p_ν	p_1	p_2	...	p_b
p_1	0	ΔJ_{12}	...	ΔJ_{1b}
p_2	ΔJ_{21}	0	...	ΔJ_{2b}
...	...	...	...	...
p_b	ΔJ_{b1}	ΔJ_{b2}	...	0

If the probabilities $q_1, q_2, \ldots, q_b$ of the occurrence of the values of the parameter p: $p_1, p_2, \ldots, p_b$ are given, then an optimal strategy is the strategy that minimizes the mean risk

$$J''' = \min_{\nu} \sum_{\mu=1}^{b} \Delta J_{\nu\mu} q_\mu$$

If we consider the general case of the choice of a many-parameter model from a given set of models $\{M_j(\Gamma_{<p_j>})\}$, then it is advisable to divide the solution of this problem into the following stages. First, for each fixed model $M_j(\Gamma_{<p_j>})$, the best combinations of the value parameters are found in accordance with the criteria proposed above; i.e., we find $M_j^* = M_j(\Gamma^*_{<p_j>})$. As a result, we obtain k models $M_1^*, M_2^*, ..., M_k^*$ with fixed parameters. From these models, using an analogous procedure again, we choose the best model.

In conclusion, we consider the possible variants of the calculation of the adequacy indices of models and control of their quality for the situations when only the values of parameters are changed in the system, but the structure of models remains the same.

We introduce the following sets: the set of models $\overline{\overline{M}} = \{ M_1, \ldots, M_\Theta \}$ of an original object $Ob^{op}_{<>}$; the set of features $\overline{P}_{cs}(t) = \{ \overline{P}_g^{(cs)}, g = 1,...H \}$ of $Ob^{op}_{<>}$; and the set of possible variants (totalities) of the feature values $\overline{\overline{P}}_{cs}$.

In addition, assume that $AD(M_\theta,\ \overline{P}_{cs})$, $\theta = 1,...,\Theta$ is a certain given adequacy index of the model M_θ relative to $Ob^{op}_{<>}$ that is characterized by $\overline{P}_{cs}(t)$ at the time instant t.

Together with the classical axioms of a metric, the adequacy functional $AD(M_\theta,\ \overline{P}_{cs})$ must possess the following additional properties (Skurikhin, Zabrodskii and Kopeichenko 1989):

(a) $AD(M_\theta,\ \overline{P}_{cs}) > 0,\ \forall\ M_\theta \in \overline{\overline{M}},\ \overline{P}_{cs} \in \overline{\overline{P}}_{cs}$;

(b) $AD(M_\theta,\ \overline{P}_{cs}^{(1)}) > AD(M_\theta,\ \overline{P}_{cs}^{(2)})$,

where the model M_θ more adequately describes $Ob^{op}_{<2>}$ with the set of features $\overline{P}_{cs}^{(2)}$ than $Ob^{op}_{<1>}$ with the set of features $\overline{P}_{cs}^{(1)}$;

(c) $AD(M_{\theta_1},\ \overline{P}_{cs}^{(1)}) > AD(M_{\theta_2}, \overline{P}_{cs}^{(2)})$,

where the model M_{θ_2} more adequately describes $Ob^{op}_{<1>}$ with the set of features $\overline{P}_{cs}^{(1)}$ than the model M_{θ_1}. It was supposed in relations (a)–(c) that the parameters of each model are optimally adjusted to the corresponding $Ob^{op}_{<>}$. It is worth noting that, under the action of different factors, both the parameters and structures of $Ob^{op}_{<>}$ can be changed. Therefore, in the estimation of the functionals involved in (a)–(c), it is necessary to take into account and predict the variation in the values of the parameters $\overline{P}_{cs}(t)$ characterizing $Ob^{op}_{<>}$ and the environment at each time instant, so as to temporally correct the structures and parameters of the model (poly-model system). Choosing the value of the time interval, for which we have to predict the values of features of $Ob^{op}_{<>}$, we should find such a compromise decision that, on the one hand, provides as accurate an estimation of $\overline{P}_{cs}$ as possible, and, on the other hand, the chosen time interval must be big enough for constructing a new model $Ob^{op}_{<>}$ and adjustment of its parameters before its operation. Moreover, the universe of events $\overline{\overline{P}}_{cs} = \overline{\overline{P}}_{cs}(t)$ that changes in time is characteristic of developing situations. Under these conditions, the approach based on interpretation of the processes of designing models and evaluating their quality by methods of modern control theory of dynamic systems with reconfigurable structure (Okhtilev, Sokolov, Yusupov 2006) is very prospective. As an example, we can consider two possible statements of the problem of controlling the quality of models (synthesis of their structure) based on the proposed dynamical interpretation of the processes occurred.

Problem A. It is required to minimize a functional that characterizes the degree of proximity of the model and $Ob^{op}_{<>}$ under the constraints on the total time of synthesizing the model and on its parameters and structures (Skurikhin, Zabrodskii and Kopeichenko 1989)

$$AD(M_\theta^{(l)},\ \overline{P}_{cs}) \to \min,$$
$$t_{st}(\mathbf{w}, M_\theta^{(l)}) \le \bar{t}_{st},$$
$$M_\theta^{(l)} \in \overline{\overline{M}},\ \mathbf{w} \in W,$$
$$M_\theta^{(l)} = \overline{\overline{\Phi}}(M_\theta^{(l-1)}, \mathbf{w}, \overline{P}_{cs}),\ l = 1,2,...,$$

where $AD(M_\theta^{(l)}, \overline{P}_{cs})$ is a functional that is used to estimate the degree of adequacy of the model $M_\theta^{(l)}$ relative to the object $Ob^{op}_{<>}$ characterized by the set of features from the set $\overline{P}_{cs}(t) = \{ \overline{P}_g^{(cs)},\ g = 1,...,H\}$; t_{st} is the total time of synthesizing a model with given properties; $\bar{t}_{st}$ is the limit admissible time of synthesizing the model; $\overline{\overline{\Phi}}$ is the operator of interactive construction of the structure of the model $M_\theta^{(l)}$; l is the current iteration number; $\mathbf{w}$ is the vector of parameters of the structural adaptation of the model; and W is the set of its admissible values.

Problem B, which is inversed to Problem A, can be represented in the following form:

$$t_{st}(\mathbf{w}, M_\theta^{(l)}) \to \min,$$
$$AD(M_\theta^{(l)}, \overline{P}_{cs}) \le \varepsilon_2,$$
$$M_\theta^{(l)} \in \overline{\overline{M}},\ \mathbf{w} \in W,\ M_\theta^{(l)} = \overline{\overline{\Phi}}(M_\theta^{(l-1)}, \mathbf{w}, \overline{P}_{cs}),$$

where ε_2 is a given constant that characterizes the admissible level of degree of adequacy of the models $Ob^m_{<>}$ of the form $M^{(l)}_\theta$; and $\theta \in \tilde{I} = \{1,...,\Theta\}$, $\overline{\overline{M}}$ is the set of possible variants of models $Ob^m_{<>}$.

From the point of view of control theory, these problems are referred to the class of problems of adaptation of the parameters and structures of objects (the models $Ob^{op}_{<>}$ are regarded as objects). The presented relations imply that, as the main criterion of the process of parametric and structural adaptation of the models $Ob^{op}_{<>}$ (or, in other words, of the control of the model quality), it is advisable to choose the condition of adequacy of models. Note that adequacy means the principal correspondence between the results of modeling and the changes and relations between $Ob^{op}_{<>}$ and the environment that takes place under real conditions, rather than the reflection of the models in all details. The main destination of the quantitative evaluation of the adequacy used at the time instant *t* of the model $M^{(l)}_\theta$ is determined by the necessity to improve to an admissible level the *confidence degree* of the decision maker that will allow him to judge the correctness of the propositions about the real object based on the data obtained in modeling (Aframchuk, Vavilov, Emel'yanov et al**.** 1998; Vasil'ev 2001; Okhtilev, Sokolov, Yusupov 2006; Kalinin, Sokolov 1985; Peregudov and Tarrasenko 1989; *Reliability and Efficiency in Engineering: Handbook* 1988; Rostovtsev and Yusupov 1991).

CONCLUSION

Resuming the aforementioned, we should note that, under modern conditions, it is very urgent to develop the methodological foundations of the theory of estimation and control of the quality of models or *qualimetry of models*. This theory is a part of the science of quality and can be decomposed into many particular applied directions in which the estimation of the quality of models employed in a certain application domain should be conducted.

Figure 4 presents as an example the basic elements of the theory of estimation and control of the quality of models developed recently, which are used

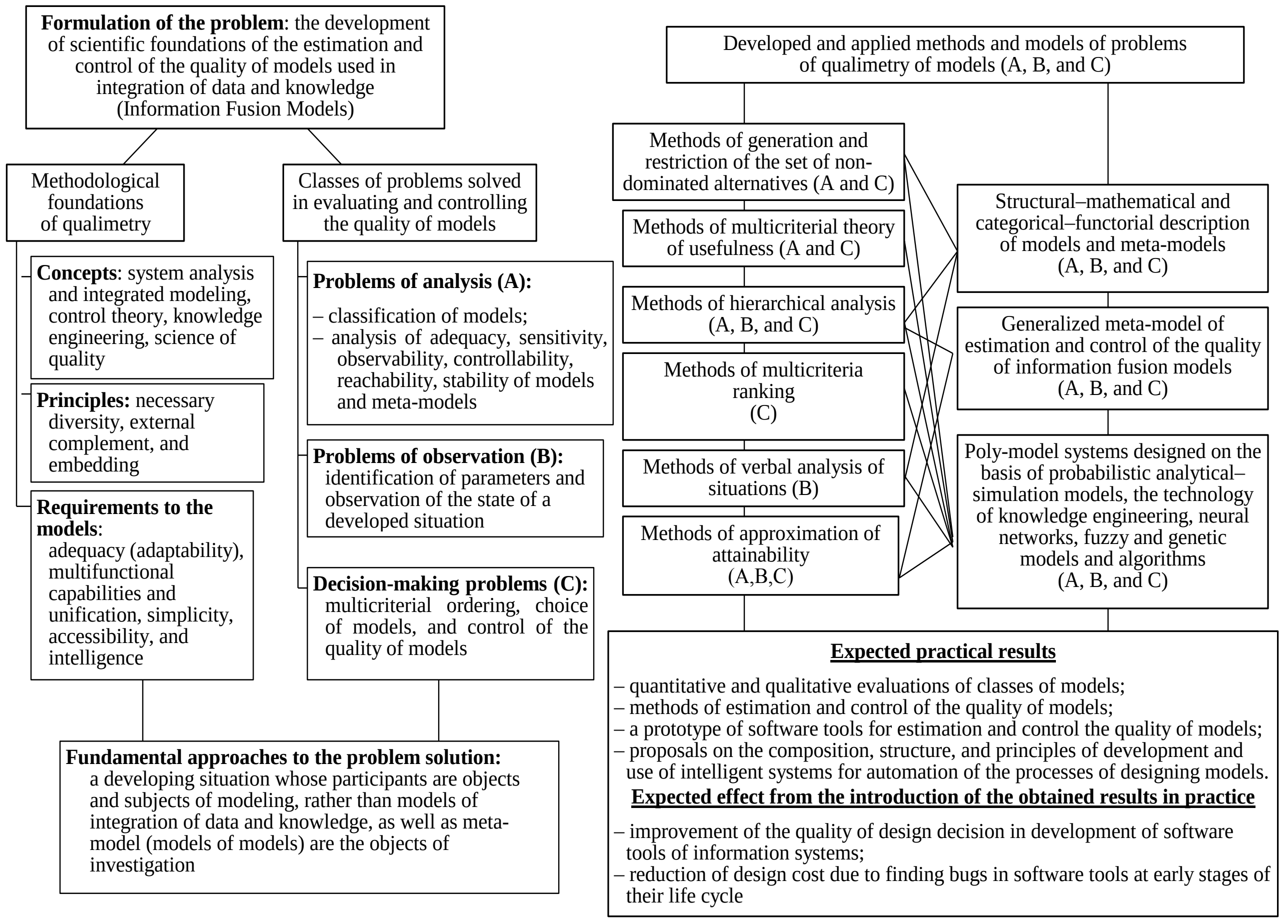

Figure 4: The methodological backgrounds of the solution of the problem of qualimetry of models employed in integration of data and knowledge

in integration of data and knowledge (Information Fusion Models) (Okhtilev, Sokolov, Yusupov 2006; Kalinin and Reznikov 1987; Yusupov 1977; Ceany and Raiffa 1981; *Fuzzy Sets in Models of Control and Artificial Intelligence* 1986). In our opinion, the development of qualimetry of models should be made in parallel in the main two lines of investigations that closely interact with each other. In the framework of the first line of investigations, the general problems based on the results obtained in solving applied problems of the theory of estimation and control of the model quality (*Reliability and Efficiency in Engineering: Handbook* 1988). It is advisable to set off the development of integrated systems for decision-making in estimation and control of the quality of models and poly-model.

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THE INTELLIGENT MONITORING TECHNOLOGY BASED ON INTEGRATED GROUND AND AEROSPACE DATA

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ABSTRACT

The new intelligent monitoring technology (IMT) developed is based on interdisciplinary methodology of creation and application of any information technology. Besides, it considers functioning dynamics and possible structure degradation of complex objects in critical situations, and operating structural dynamics of complex objects. Unlike existing systems, the IMT is universal, and it includes the combined methods and algorithms of decision making in various classes of monitoring problems, forecasting and safety control of complex objects regardless to their appointment.

Keywords: monitoring, intelligent information technology, integrated ground and aerospace data, complex natural-technical objects, data and information fusion.

1. INTRODUCTION

At the present day, the stable market for aerospace services customer foundation is being one of the major problems of the aerospace technology and system development. The problem core is concerned with the development of technologies and systems for the aerospace data collection, processing, treatment and application. The monitoring of complex natural, organizational and technical objects (CO) is one of the actual domains of ground and aerospace data applications.

Information sources for this kind of objects monitoring include technical state of constructions collected from the space-navigation data, technical parameters of units and systems, aerospace data about objects and adjoining territories.

Complication of CO is resulted in expansion of their parameters to be measured and controlled. Today the number of such parameters can achieve several hundreds or thousands for various classes of technical systems (Steinburg, Bowman, White, 1998; Stark 2004). Usually CO state monitoring is not automatized completely. Thus, operators receive semantic information about some elements of CO rather than information characterizing integral CO states. To estimate CO state the operators should be able to analyze various context conditions of interaction between CO elements and subsystems. There are no universal methods and technologies for solution of the above-mentioned problems (Okhtilev, Sokolov, Yusupov 2006). Existing program systems for gathering, processing, and analysis of CO telemetry usually depends on characteristics of particular control objects and is not adaptable to undesired alteration of objects' structure. The methods and tools for construction of monitoring algorithms and systems are very specific and can be used in narrow domains. The problems of CO monitoring were investigated first of all for aerospace and electric power systems (Okhtilev, Sokolov, Yusupov 2006). The most important results were received in this domain. However, semantic interpretation of integral CO states remains the prerogative of operators.

Other feature of modern monitoring system for CO (MS CO) is the changeability of their parameters and structures as caused by objective and subjective reasons at different stages of the MS CO life cycle. In other words we always come across the MS CO structure dynamics in practice. Reconfiguration is a widely used variant of the CO structure control. Reconfiguration is a process of the CO structure alteration with a view to increase, to keep, or to restore the level of MS CO operability, or with a view to compensate the loss of CO efficiency as caused by the degradation of its functions. But, unfortunately, now CO reconfiguration is not tied in with monitoring and control processes (Ivanov, Sokolov, Kaeschel 2010; Ivanov, Sokolov 2010; Sokolov, Ivanov, Fridman 2010).

So the aim of our investigation is to develop technologies oriented to concurrent on-line user software assurance for all sorts of measuring information (information fusion) specifying states of complex process (situation assessment) at all phases of CO life cycle and control function in real time.

This aim should be achieved by here suggested artificial intelligent information technology and modern control theory (Okhtilev, Sokolov, Yusupov 2006; Ivanov, Sokolov, Kaeschel 2010; Ivanov, Sokolov 2010; Sokolov, Ivanov, Fridman 2010). The suggested newly designed information technology is based on decision of basic research problem. This problem is monitoring and control of states of CO and complex process (situation assessment). The basis of this artificial intelligent information technology is flow computing models exploitable by state hipping (constraint programming) in real time. According to accepted classification the present technology covers the following levels of information fusion (Steinburg, Bowman, White 1998):

Level 1: Data fusion for object assessment;

Level 2: Information fusion for situation assessment;

Level 3: Information fusion for situation prediction.

In addition to solving research problems it is necessary to develop ways and organizational forms of the most effective implementation of the proposed IMT. This is the second objective of the research.

2. THE MAIN TASKS AND RESULTS OF INVESTIGATION

2.1. Investigation overview and related work

Analysis of a market dealing with modern software complexes oriented to monitoring automation for the states of complex technological processes shows that the existing software complexes have narrow application scopes strictly specified by controlled objects; they also have limited capacities for adaptation to environmental disturbances. This is why there exist many monitoring applicable software complexes having contiguous functionality and differing in organizational methods of computational processes, and in used operational environment. As an example three directions in practical implementation of analyzed software complexes could be mentioned (Steinburg, Bowman, White 1998; Okhtilev, Sokolov, Yusupov 2006; Norenkov 1998; Okhtilev 1999; Okhtilev 2000; Sethi and Thompson 2006):

1. Widely applied real time dynamic expert systems like G2 (software firm Gensym, USA), RT Works (software firm Talarian, USA), COMDALE/C (Comdale Techn., Canada), COGSYS (SC, USA), ILOG Rules (ILOG, France) are worth mentioning.
2. The results received through application of a so-called theory of unfinished computing based on constraint programming methods and the theory of multi-agent artificial intelligent systems. The following software packages demonstrate some advantages of this approach: integrated software product SPRUT (OCTORUS) and intelligent mathematical problems solver UniCalc.
3. The third direction incorporates so-called data fusion and control systems like SCADA-systems (Supervisor Control and Data Acquisition – data fusion and control system, operator’s interface, etc.). Well known products: Genesis, IsaGRAF, TraceMode could be good examples of this development line.A profound study of theoretical results showed that there exists a great number of publications in the area of measuring information processing and analysis methods, on the other hand, research in the areas of design automation for monitoring software complexes, development of techniques allowing to arrange for parallel processing and analysis of measuring information in computing environment with changing structure are poorly reflected in literature. The impact of types and structures of the processed information on the composition and structure of the considered software complexes is not well investigated either.

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Development of flow-oriented knowledge-representation models, methods, and algorithms for monitoring and control of objects and for reconfiguration of monitoring system plays the important role in decision of the main problems of synthesis and intellectualization of monitoring technology and system for complex technical objects under dynamic conditions in real time. This task includes the following subtasks:

- development of methodological basics for accumulation and use of ill-formalized knowledge about states of complex technical objects under "rigid" constraints (for example, real-time operation mode and recurrence of computational processes) applied to both process of knowledge accumulation and

process of state estimation; development of methodological basics for structure reconfiguration of objects and of monitoring system (first line of investigation);
- development of model-and-algorithmic basics for analysis and synthesis of reconfigurable monitoring system (second line of investigation);
- development of new information technology for creation and maintenance of monitoring software and software prototype; approbation of the technology in typical application domains (third line of investigation).

Our investigation in the area of the structure dynamics control problems have shown that these problems belong under the class of the CO structure – functional synthesis problems and the problems of program construction, providing for the CO development (Sokolov, Yusupov, Okhtilev, Maydanovich, 2010; Okhtilev 2004; Okhtilev, Vasiliev 2004; http://litsam.ru).

The main feature and the difficulty of the problems, belonging under the above class is a follows: optimal programs, providing for the CO main elements and subsystems control can be implemented only when the lists of functions and of control and information-processing algorithms for these elements and subsystems are known.

In its turn, the distribution of the functions and algorithms among the CO elements and subsystems depends upon the structure and parameters of the control rules, actual for these elements and subsystems. The described contradictory situation is complicated by the changes of CO parameters and structures, occurring due to different causes during the CO life cycle. At present the class of problems under review is not examined quite thoroughly (Okhtilev, Sokolov, Yusupov 2006; Sokolov, Yusupov, Okhtilev, Maydanovich, 2010; Okhtilev 2004; Okhtilev, Vasiliev 2004; http://litsam.ru). The new theoretical and practical results were obtained on the following lines of the investigation: *the synthesis of the CO technical structure for the known laws of CO functioning (the first direction); the synthesis of the CO functional structure, in other words the synthesis of the control programs for the CO main elements and subsystems under the condition that the CO technical structure is known (the second direction); the synthesis of programs for CO construction and development without taking into account the periods of parallel functioning of the actual and the new CO (the third direction); the parallel synthesis of the CO technical structure and the functional one (the forth direction).*

Several iterative procedures for solving of the joint problems, concerning the first and the second directions are known at present. Some particular results were obtained within the third and the forth directions of investigations. All the existing models and methods for the CO structure – functional synthesis and for the construction of the CO development programs can be applied during the period of the internal and external design when the time factor is not very essential. Therefore, the development of new theoretical and technologies bases for CO structure-dynamics monitoring and control which are based on integrated ground and aerospace data is very important now.

2.2. The results of investigations

Within the first line of investigations the following scientific and practical results have been obtained by now.

It was established that the change from an automated processing of measuring information to a computer-aided analysis of received materials involves semantic aspects of data representation in place of syntactic ones. Thus, the information about control objects should rather be regarded as a set of interrelated parameters jointly characterizing objects' technical state than a simple collection of measurements. This provided for a conclusion that the metric-space concepts, typically used in simple monitoring problems, are weak and not suitable for our purposes, hence more general constructions should be used.

It was proved that the parameters of objects' technical states can be described via a system of open sets forming a base of topology. It was assumed that the set of parameters has a topological structure. Thus a system of neighborhoods (meeting the axioms of topological spaces) was established for each element. The notion of a technical state was worked out. By the technical state we meant an abstract collection of data including whole information both about object's current attributes and the state of computations within the monitoring process. This view lets optimize computations in order to receive monitoring results in real time. The following basic statements were proved: the whole set of technical-state parameters constructed trough the proposed model of knowledge representation is a lattice or a lattice ordered set; if the set of technical states have the greatest element and the least element (defining the initial data and the results correspondingly), then a complete lattice (an algebra over the set) can be formed via a construction of additive and multiplicative lattices; necessary and sufficient conditions for topology base existence were obtained for the set of technical parameters. The last result is very important, as the constructed topology is used for whole description of possible technical states and for planning of states analysis (for construction of computational scheme).

Moreover w*ithin the first line of investigations* we have been obtained the following the results (Okhtilev, Sokolov, Yusupov 2006):

- Formal description of all possible kinds of controlled states (assessed situation) accounting for their adequacy to actual actions and processes on controlled object caused by application of different mathematical apparatus for various functional objects. Multi-model formalization intends for describe actions and processes on the controlled object;

- New integrated methods of program synthesis for automatic analysis (AA) of measuring information (MI) about CO states were worked out. These methods, as distinct from known ones, give an opportunity of, firstly, interactive intellectual processing of data and knowledge about CO states for different physical properties (for example, functional parameters, range parameters, signal and code parameters, and integrated parameters) and for different forms of states description without reference to their physical features and, secondly, automatic generation of alternative program schemes for MI analysis according to the objectives of CTO control under the presence of changing environment;
- New algorithms of automatic synthesis of AA MI programs were proposed for poly-model description of monitoring processes via attribute grammars, discrete dynamic systems, and modified Petri nets. Applying of polytypic models resulted in adequate adaptation of the algorithms to different classes of CO. Another distinguishing feature of the algorithms lied in application of underdetermined calculation and constraint-driven programming and provided that CTO states could be estimated rather adequately even if some parameters were omitted and the measuring information was incorrect and inaccurate;
- A general procedure of automatic (computer-aided) synthesis of CO monitoring programs was developed. This procedure includes the following steps (Okhtilev, Sokolov, Yusupov 2006; Okhtilev 1999; Okhtilev 2000; Sokolov, Yusupov, Okhtilev, Maydanovich, 2010; Okhtilev 2004; Okhtilev, Vasiliev 2004).

The 1st step. Description of conditions and constraints for the problem of AA MI programs synthesis via a special network model connecting input data with goals. An operator (he need not be a programmer) uses a special problem-oriented language to execute this step.

The 2nd step. Automatic existence analysis for a solution of AA MI problem that is defined via a formal attribute grammar.

The 3rd step. If the solution exists then the alternative schemes for AA MI programs are generated and implemented in a special operational environment (problem solver of the CTO monitoring system).

The main advantage and substance of the proposed procedure is simple modeling of MI sources (models generation) that can be performed by a non-programming operator in the shortest time and the real-time implementation of the intellectual methods and algorithms of MI processing and analysis for arbitrary structure of the measuring information.

The proposed methods of monitoring automation and modeling let switch from heuristic description of the telemetry analysis to a sequence of well-grounded stages of monitoring program construction and adaptation, from unique skills to unified technologies of software design. These methods are based on a conclusion that a functional description of monitoring process is much less complicated than detailed examination of software realizations. Consecutive specification of software functions is the ground of technologies to be used for creation of monitoring systems. The suggested technology of continuous design process includes such well-known phases as new proposal phase based on special operational environment (Sokolov, Yusupov, Okhtilev, Maydanovich, 2010; Okhtilev 2004; Okhtilev, Vasiliev 2004).

Within the second line of investigations the following scientific and practical results have been obtained by now (Okhtilev, Sokolov, Yusupov, 2006; Ivanov, Sokolov, Kaeschel 2010; Ivanov, Sokolov, 2010; Sokolov, Ivanov, Fridman 2010).

System analysis of the ways and means to formalize and solve the problem of the control over structure dynamics of monitoring system (MS) servicing CO under changing environment was fulfilled. It was shown that the problems of structure-functional synthesis of monitoring systems and intellectual information technologies as applied to complex technical objects and the problems of CO structure reconfiguration are a special case of structure-dynamics control problem. Other variants of structure-dynamics control processes in MS are: changing of MS objectives and means of operation; reallocation of functions, tasks, and control algorithms between MS levels; control of MS reserves; transposition of MS elements and subsystems.

The basic concepts and definitions for MS structure-dynamics control were introduced. It was proposed to base formulating and solving of the structure-dynamic control problems on the methodologies of the generalized system analysis, the modern optimal control theory for the complex systems with reconfigurable structures and artificial intelligence. The stated methodologies find their concrete reflection in the appropriate principles. The main principles were marked out: the principle of goal programmed control, the principle of external complement, the principle of necessary variety, the principles of poly-model and multi-criteria approaches, the principle of new problems.

During our investigations the main phases and steps of a program-construction procedure for optimal structure-dynamics control in MS were proposed. At the first phase forming (generation) of allowable multi-structural macro-states is being performed. In other words a structure-functional synthesis of a new MS make-up should be fulfilled in accordance with an actual or forecasted situation. Here *the first-phase* problems come to MS structure-functional synthesis.

At *the second phase* a single multi-structural macro-state is being selected, and adaptive plans (programs) of MS transition to the selected macro-state are constructed. These plans should specify transition programs, as well as programs of stable MS operation in intermediate multi-structural macro-states. The *second phase* of program construction is aimed at a solution of multi-level multi-stage optimization problems.

One of the main opportunities of the proposed method of MS structure dynamics control (SDC) program construction is that besides the vector of program control we receive a preferable multi-structural macro-state of MS at final time. This is the state of MS reliable operation in the current (forecasted) situation. The combined methods and algorithms of optimal program construction for structure-dynamics control in centralized and non-centralized modes of MS operation were developed too.

The main combined method was based on joint use of the successive approximations method and the “branch and bounds” method. A theorem characterizing properties of the relaxed problem of MS SDC optimal program construction was proved for a theoretical approval of the proposed method. An example was used to illustrate the main aspects of realization of the proposed combined method.

Algorithms of parametric and structural adaptation for MS SDC models were proposed. The algorithms were based on the methods of fuzzy clusterization, on the methods of hierarchy analysis, and on the methods of a joint use of analytical and simulation models

The SDC application software for structure-dynamics control in complex technical systems was developed too.

Within the third line *of investigations the following scientific and practical results have been obtained* by now the pilot versions of computer-aided monitoring system (CMS) for CO states supervision (in space systems and atomics); it uses special operational environment (Sokolov, Yusupov, Okhtilev, Maydanovich 2010; Okhtilev 2004; Okhtilev, Vasiliev 2004), real-time database management system, multi-window interface, and programming language C/C++.

The prototypes of CMS belong under the class MMI/CACSD/SCADA/MAIS (man-machine interface/ computer-aided control system design/supervisory control and data acquisition/ multi-agent intellectual system).

Table shows technical and operating characteristics of the developed software prototype.

CONCLUSION

The new intelligent monitoring technology (IMT) considered provides integrated use of the available information of complex objects states and about a critical situation and its predictable consequences.

Table: Peak capacity and characteristics of monitoring software prototype for co state supervision

CHARACTERISTICS	VALUES OF CHARACTERISTICS
The number of parameters to be simultaneously analyzed	up to 1.6×10^{7}
Parameter range for integer parameters	from –2147483648 to +2147483647
Parameter range for real parameters	15 decimal digits with exponent part from –307 to +308
The number of parameters to be analyzed within one session	up to 6×10^{10}
Time accuracy for all events and phenomena	up to 10^{-3}
Complexity of unified structures	– situation matrix (up to 512 situations); – finite-automaton models; – linear-bounded automatons; – unique models of an arbitrary strength; – universal applications.
The number of forms	Is restricted according to ergonomic and hardware limitations.

The main possibilities of the IMT are shown below:

- The real-time processing of a considerable quantity of diverse parameters;
- The data and knowledge simultaneous processing;
- The intelligent analysis providing of the measuring information of any physical nature on the distributed computer complexes;
- The results visualization of the processing in a 2D and 3D format, the interface with geoinformation systems implementation;
- The ability for creation of concrete monitoring systems for non-professional users (non-programmers).

The IMT developed is based on interdisciplinary methodology of creation and application of any information technology. Besides, it lets consider functioning dynamics and possible structure degradation of complex objects in critical situations, and operate structural dynamics of complex objects. Unlike existing systems, the IMT is universal, it includes the combined methods and algorithms of decision making in various classes of monitoring problems, forecasting and safety control of complex objects regardless to their appointment.

Now IMT is successfully implemented in monitoring systems serving space branch, nuclear engineering, and the chemical industry.

IMT also can find applications in the situational centers, decision-support systems for management of emergency situations, monitoring of the difficult natural processes requiring processing and visualization of a considerable quantity of the diverse data.

The possibility of creation distributed, cross-border monitoring solutions for global ecosystems is supported by the IMT. The monitoring system mentioned is being used for the forecasting and the risk reducing of natural and anthropogenic accidents impacts. This is the reason for use the IMT as foundation of the actually nascent International Global Monitoring Aerospace System (IGMASS).

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A CONTAINER TERMINAL MANAGEMENT SYSTEM

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ABSTRACT
This paper aims to use agent paradigm for modeling a Container Terminal Management System (CTMS). Our methodology is organized along three main axes. The first objective is to describe the overall architecture of a Container Terminal (CT), its actors and modeling container's handling process. The second one addresses the problem of safety in CT and specially the case of hazardous material. The latter proposes an agent approach for the development of CTMSs in an open source environment.

Keywords: Multi Agent System, Container Terminal, Container Terminal Management System, Agent Modeling Language

1. INTRODUCTION

The main problem of managing a CT is to ensure the mobility of containers passing through the sea port to deliver them to recipients in the best conditions. Thus, optimization of container handling is the basis for improving the performance of CT and therefore its competitiveness. Each handling order must be made by agents operating in the CT satisfying a set of constraints. On the one hand, container handling is governed by internal regulations of the port in order to respect its organization. On the other hand, there's a set of constraints related to the nature of the containerized goods, for example the case of segregation conflict between the classes of hazardous materials in storage area. In addition, a seaport may be subject to different hazards introducing the rupture of its operations. Following the consequences magnitude of these dangerous hazards, it is necessary to have a risk management approach. Although applying a risk management approach on a seaport will have a negative impact on its performance. Thereby solving this problem amounts to solving a problem of decision-making characterized by reconciliation between the security aspect and the performance of the sea port.

On average, inspected containers rate is 2% of the flow of containers through the seaport. Constrained by the impact of security inspections of port performance and cost of resource allocation for their implementation, the inspection rate of containers in Le Havre seaport is 0.5% (Dahlman 2005). Therefore, the appropriateness of the inspected containers choice is critical. The choice of these containers is a multi-criteria and multi-actors decision making problem.

Using traditional risk management approaches can identify risks; define a strategy for mitigating their impact and their probability of occurrence. However, these approaches are limited in their ability to dynamically manage risks. For this purpose the definition of a risk management approach which takes into account the nature of the CT and the impact of these security procedures on the performance is required.

Seaborne containerized cargo in the world has seen a great evolution from 50 million TEUs (Twenty-foot Equivalent Unit) in 1985 to 350 million TEUs in 2004 (Kim and Gunther 2007). The relocation of production plants, the increased trade between countries and the development of a new generation of container ship with a capacity ranging between 8,000 and 10,000 TEUs (Ottjes and al, 2007) explains the keen interest for this mode of transport that allows a cost-effective to transport large quantities of goods (Lun and al 2010).

Competition among shipping companies for the attraction of a large flow of container has exceeded the maritime boundaries represented by the providers of maritime transport hub ports to accommodate ships. The evolution of the freight passing through a CT, the complex nature of these platforms and port handling dynamic processes require the development of a performance Container Terminal Management System (CTMS) to prevent the potential risks.

Using a multi-agent system allow to describe the overall operation of a system from a description of the behavior of its actors and define a model of decision-making correlated with the situational context (Le Grusse 2001). The application of Distributed Artificial Intelligence (DAI) will allow the establishment of a collaborative decision-making based on negotiation between stakeholders to address the problem of multi-actor decision-making.

The long term goal of this work is to achieve the realization of a CTMS representing reality in real time handling operations by collecting the characteristics of the containers. In addition, it includes a decision-making process that analyzes historical data provided by traceability systems to target fraudulent containers. This decision-making process is based on the use of a fuzzy rules based system. The implementation of

CTMS will evaluate the effectiveness of the decision support system for targeting of fraudulent containers and its impact on the performance of the CT. In this work, we are particularly interested in the following objectives:

- The first objective concerns the architecture description of the CT, the specification of port stakeholders and modeling container handling process.
- The second goal addresses the risk management of the containers handling and specially the case of hazardous materials.
- The third objective concerns the specification of a CTMS based on agent paradigm and the integration of the security aspect through a decision making process for the prevention of risk scenarios and targeting of fraudulent containers.

The remainder of this paper is structured as follows: the second section discusses the modeling of the CT and the container handling process. The third section addresses the problem of risk management in a CT and provides an overview on the works done in this area and specifically the risk management during handling containers. The fourth section describes our CTMS model based on agents and taking into account the security aspect. Finally, we conclude by describing the limitations and perspectives of this work.

2. CONTAINER TERMINAL

The container represents the standardization unit of cargo transport; he has promoted the development of intermodal transport networks. Thereby the growth of the number of containers passing through a CT has assigned the role of the primary node of the global supply chain to these maritime platforms (Longo, 2010). In addition, the CT is a multimodal transport area (Ottjes et al, 2007).

In general a CT can be described as physical flow open system with two external interfaces (Steenken 2004), land interface and maritime interface. The CT is classified into a set of zones acting as buffers for the synchronization and coordination between handling operations. Figure 1 gives an overview of the architecture of a CT.

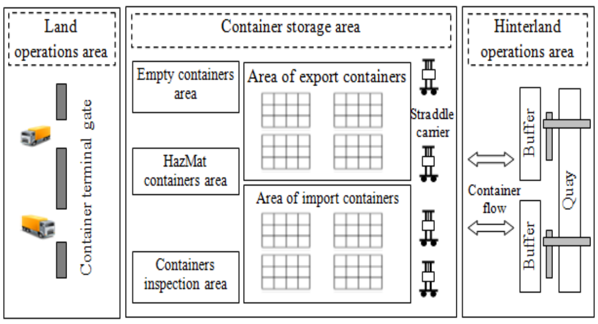


Figure 1: Overall layout of a container terminal

The structure of a CT is defined as a strategy that takes into account the nature of the handling operations (for example the case of a transshipment CT) in addition to the type of container handling material. (Dubreuil 2008) (Henesey 2006) (Wong and Yong 99) (Petering 2008) (Bakht and Ahmed 2008) identify three main areas: The area of land operations, the container storage area and hinterland area. These areas are classified into sub-areas dedicated by the type of port operations or the nature of the goods.

Container handling is a set of transport and storage operations to ensure the movement of goods between the two interfaces of the CT. In addition, the handling equipment (figure 2) has a great influence on the processes of import, export and transshipment containers. Especially in the case of the automation of handling operations in the Rotterdam seaport that distinguishes it from other seaports (Liu and al 2002). Thereby, a good specification of handling equipment is the basis for description of handling processes. (Steenken 2004) has classified container handling equipment into two categories:

- The first category includes the horizontal transport equipment containers such as trucks, containership and Auto-Guided Vehicles (AGV).
- The second category is a set of materials capable of lifting containers vertically, such as Quay Cranes (QC) and Straddle Carrier (SC).

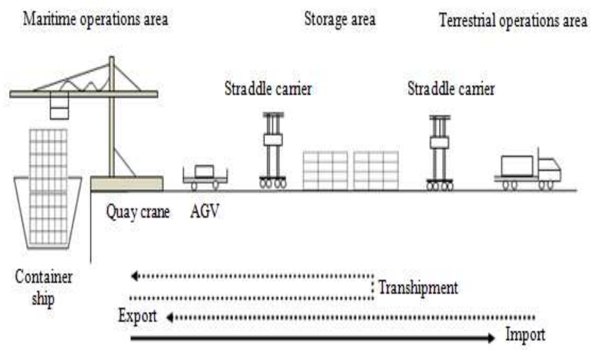


Figure 2: Container flow and handling equipment

To manage successfully a container terminal, we need to integrate informations sensors (RFID, GPS, GPRS, etc.) and information systems. In our case, we use our information system (Boukachour 2011), called GOST (Geolocalisation, Optimisation and Securisation of the Transport of containers).

GOST is a Web Services platform coupled with technological solutions to track and secure container shipping. It is designed to monitor physical movements, administrative schedules and planned shipment information in real time based on information traceability, with possible interventions to prevent malfunctions and risks of failure. GOST is not a standalone system but is interfaced with numerous existing information systems (port system, software solutions for the transit and port traction…), access geospatial data (tag GPS / GPRS, embedded computing, RFID, etc) and use secure connections (H24 and APSAD3), with appropriate services intervention if necessary. It is accessible via secure Web Services to all logistics agents. The GOST platform provide real-time and delayed time information and alerts needed to manage identified risk situations.

In order to automatically identify containers and to collect information about it, we use the concept of intelligent product. This concept comes from the field of industry, it has been adapted for the creation of intelligent containers. An approach based on the equipment of containers with RFID tags and sensors to measure temperature, humidity from the real environment. Thus, the intelligent container is considered as an entity carrying information able to communicate its characteristics to other systems and therefore to participate in decision making process. The works of (Alfaro and Rabald 2008), (Janssens-Maenhout and al 2009) and (Rizzo and al 2010) represent a concrete application of this concept, for example using intelligent containers for checking food transport conditions or to detect the traffic of radioactive materials in the containers.

3. RISK MANAGEMENT ON THE CONTAINER TERMINAL

The complexity of risk management in global supply chain requires a concentration of preventive procedures on these main links. To this end, many of these procedures are concentrated at the level of CTs due to their importance in world trade. Risk management in a CT for securing the transport container is a set of preventive measures:

- Container Security Initiative CSI
- Customs-Trade Partnership Against Terrorism C-TPAT
- Proliferation Security Initiative PSI
- Mega ports initiative to prevent nuclear smuggling.

In the literature, especially in the case of hazardous materials the works of (Rigas and Sklavounos 2002) (Milazzo and al 2009) (Winder and Zarei 2000) were based on a post hoc analysis of the consequences of an accident during the container handling to identify special interventions strategies adapted to the studied case.

The huge flow of containers passing through a seaport imposes the adoption of a security approach for preventing risks and detecting fraudulent containers passing trough CT (Milazzo and al 2009). Risk management related to the handling of hazardous materials at a seaport is constrained by the unsuitability of conventional methods of risk management to the dynamic of its environment. In addition, the confidentiality of information due to their economic values and the concurrence between shipping firms is a handicap for decision making process. Thus, the definition of a new approach that takes into account the dynamics, complexity and uncertainty of CT information is a promising approach to assist the decision makers to prevent risks.

4. SYSTEM DESIGN

To design our CTMS, we use a Use Case Driven Approach (UCDA) in order to specify the business process to integrate. In addition, the structure into several sub-systems allows a modular system design comprising interrelated treatments in the same sub-system and promotes the reuse of these modules for other applications.

Modeling a CTMS is a laborious task and involves the description of the behavior and roles of various components of this system. The specification complexity of CT business process and interdependence between the actors throws the proposed models quality into question. In order to ensure proper system design we have adopted the concepts described below.

It does not seem feasible to get a formal description of a complex system based on informal description on its operation, especially in the case of CTMS. The different modes of operation between the CTs in the same port, the dependence on type of handling equipment and management policy applied imposes a specific model for each CT.

In our case, to model the CTMS we opted for UCDA. The basic concepts of this approach are the actors and their actions. An actor is a specific role played by a user and represents a category of users of the system. An actor can be considered as a class and users are the instances. Use cases are expressed in natural language with terms of the studied problem domain (Regnell and Kimbler 95). Use cases are an artifact that establishes the desired behavior of the system and interactions between different actors and the sequences of actions needed to achieve a result.

Use cases are a powerful tool to capture functional requirements of the system. Several methods use this approach, such as the Unified Process method, to agile development of applications. The main advantage of this approach manifests itself in facilitating the analysis process needs while keeping users at the heart of the process by adopting these requirements in natural language. The adoption of UCDA to study the system specifications will ensure consistency between the needs of users and the functional aspect of the system.

The analysis of an entire complex system as one atomic unit is a tedious task. To address the complexity problem of CTMS we conducted a division of the problem based on the structuring technique. Structuring is a fundamental technique for classifying the CTMS into several sub-systems in order to reduce its overall complexity, reduce the phase test complexity and validate its consistency with specifications. Good structure is characterized by a strong cohesion between the component entities of the same subsystem, thus reducing the interactions between subsystems.

Therefore, a weak coupling limits the impact of malfunction or modification of a subsystem on the entire system. The division should be led by the evaluation criteria the performance and the robustness of the system.

The reuse concept reduces the development time of a system while ensuring its reliability. Reuse is to design a system as a set of specialized entities reusable by different modules of the system. The adoption of this approach limits the impact of changes on the overall system and reduces the development cycle by eliminating repetitive tasks. Reuse can reduce the development cycle by removing repetitive tasks such as unit testing of modules and focuses on the integration phase of all system components.

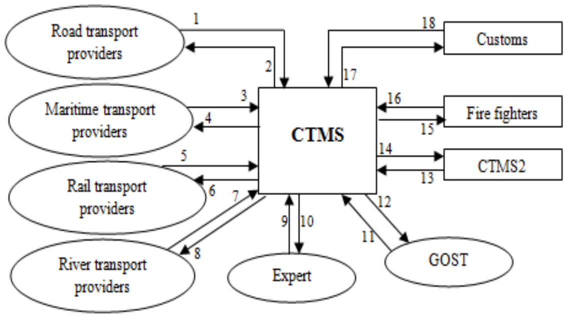
The CTMS development approach is structured in four main steps:

- Context diagram: is a primary step for the identification of system boundaries and interactions with external actors;
- Classification of the system : classification into several subsystems based on a functional grouping of consistent entities with the same goal;
- Use Case diagram: in the first step we proceed by specifying the use case diagram to identify the overall system's main actors and their roles. In the second step we define a use case diagrams for each subsystem;
- Agentification: agents are assimilated with the actors and handling equipment existing in the CT. We will proceed with a definition of all the agents forming composing the system and by specifying their functions and interactions.

5. APPLICATION

Initially, for modeling the proposed CTMS in consistent with the approach described above, we have proceeded with a macroscopic description of the system and its interactions with other actors in its environment. The second part focuses on a detailed specification of the system's agents, and their interactions.

The context diagram is the basis of a preliminary study to locate the system in its environment and identify the flow of information exchanged with external actors and related fields. In the studied case, the CTMS exchange information with a set of transport provider to prepare procedures for receiving and shipping containers. The CTMS is powered by the knowledge of experts and alerts from GOST system. In addition, it exchanges with other organizations representing related fields such as customs for the collection of information about the content and origin of the container or the firefighters in the event of an accident occurring (Figure 3).



- [1 ; 3 ; 5 ; 7] : inform CTMS about containers delivery
- [2 ; 4 ; 6 ; 8] : inform transport providers of the availability of containers
- [9] : provide knowledge for the prevention of risk
- [10] : analyse new cases
- [11]: send alerts and track the status of containers
- [12] : request information about containers status
- [13 ; 14] : Exchange information with other CTMS
- [15]: provide information about the containerized goods accident
- [16] : respond to occurrence of an accident
- [17] : target containers for inspection
- [18] : provide to system information about container

Figure 3: Context diagram of the CTMS

The aim of the proposed approach is to model a CTMS by classifying the MAS into several sub-systems in order to ease the development phase. The classification is to group agents with similar goals to form coherent subsets. In addition, the classification of the system is guided by criteria for assessing the quality of grouping the agents such as the strong cohesion between the agents of the same subsystem and the weak coupling between subsystems.

The proposed CTMS is composed of two main parts, the first one deal with decision making for risk management and consists of three subsystems: learning subsystem, supervision subsystem and planning subsystem. The second part of the system deals with handling operations in the CT. It consists of three subsystems: representation subsystem, interfacing subsystem with road transport providers, interfacing subsystem with maritime transport providers (Figure 4).

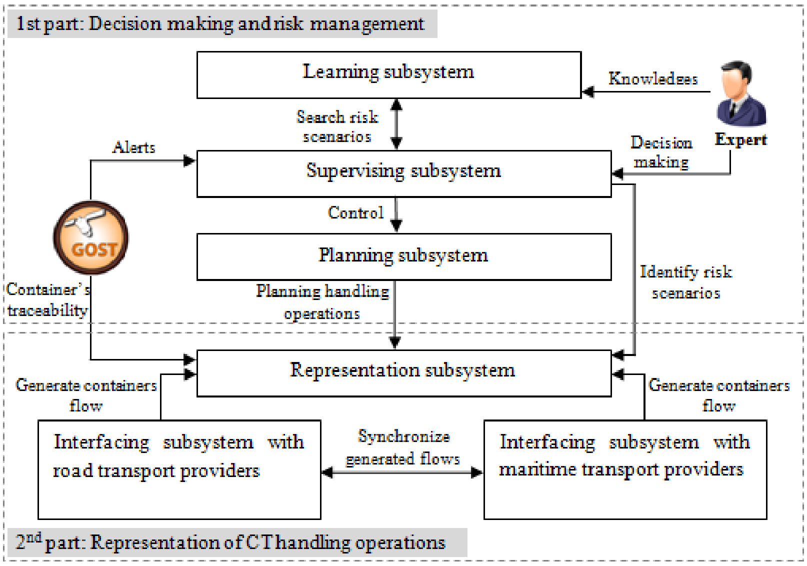


Figure 4: Classification of the CTMS into subsystems

Communication between the subsystems of the CTMS is based on an exchange of messages for the dissemination of orders and planning handling operations. The agents use the Agent Communication Language (ACL) developed by the Foundation for Intelligent Physical Agents (FIPA).

To address the complexity of modeling business processes in a CT, the specification of the behavior of individual agents at the micro level of an MAS allow the reproduction of the overall functioning of the CT in the collective interactions of agents at the macro level of the MAS. Modeling of the proposed system and specifying its functions are performed using the Agent Modeling Language AML (Whitestien, 2004).

Using AML, agents diagram allow the specification of the overall CTMS agents and gives an overview of the MAS architecture (figure5). In addition, it specifies all the interactions and dependencies between the agents by social associations.

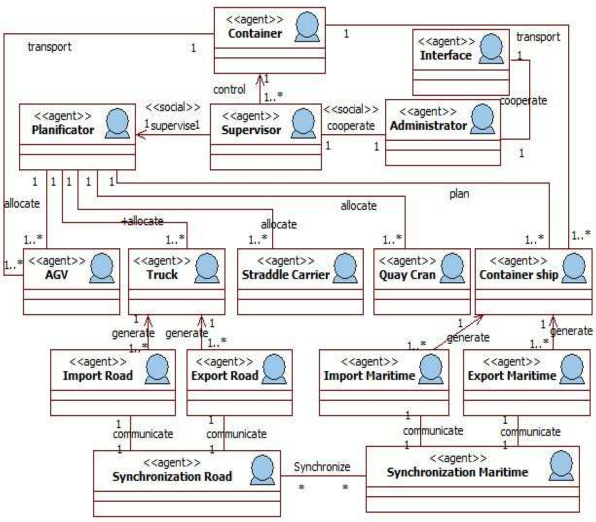


Figure 5: CTMS overall agent diagram

The agents composing the system are intentional, follow the BDI model (Beliefs, desires, intentions) they have a description of their environment and knowledge about other agents. In addition, the definition of a learning process will allow adding of new knowledge to the CTMS and therefore a continuous adaptation of the system for the detection of new risk scenarios.

5.1. Interfacing subsystem with road transport providers

It represents all road transporters providing container transport to the CT and delivers the imported containers to customers. It ensures the generation of the input and the output flows at the terrestrial interface of the CT (figure6).

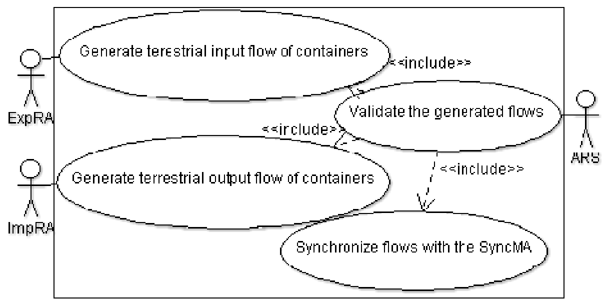


Figure 6: Use case diagram of interfacing subsystem with road transport providers

This subsystem consists of three agents:

- Export Road Agent (ExpRA): generates the flow of trucks carrying containers to the CT and thus the input flow of containers.
- Road Agent Import (ImpRA): generates the flow of trucks delivering containers to customers of CT and therefore the output flow of the terrestrial interface of the CT.

- Synchronization Road Agent (SyncRA): validates the generated container flows and cooperate with the SyncMA to ensure the support of all containers.

The functioning of this subsystem is controlled by the SyncRA, its main role is to ensure the concordance of the input and output containers flows in the terrestrial and maritime interface of the CT. It starts by sending an order to ExpRA to recover the list of generated containers at the terrestrial area. The SyncRA requests the list of generated containers at the maritime interface in order to generate the trucks delivering them to customers by ImpRA (figure7).

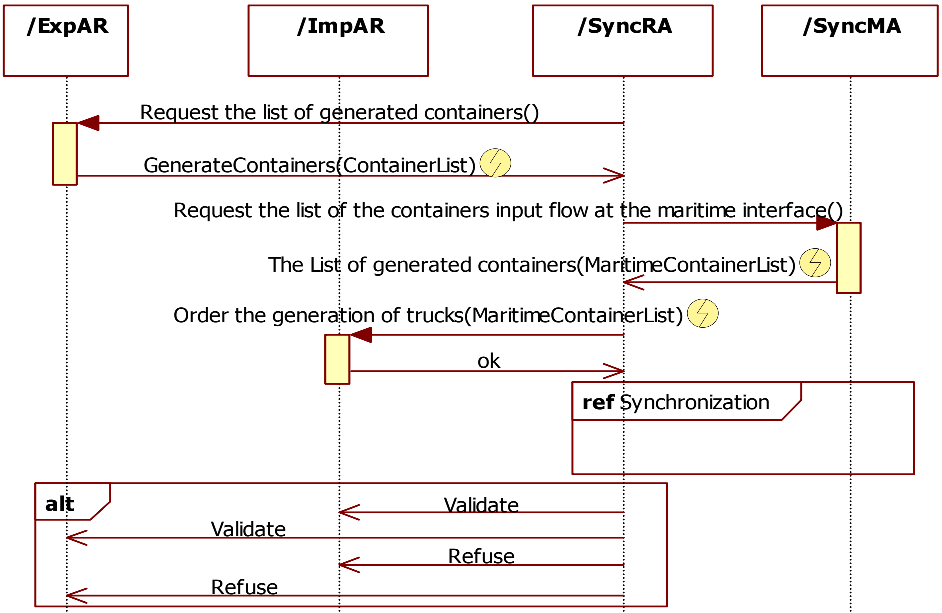


Figure7. AML Communicative sequence Diagram of the interfacing subsystem with road transport providers.

5.2. Interfacing subsystem with maritime transport providers

Ensures the generation of the input flow and the output flow of containers generated at the maritime interface of CT. The following figure describes the use case of this subsystem:

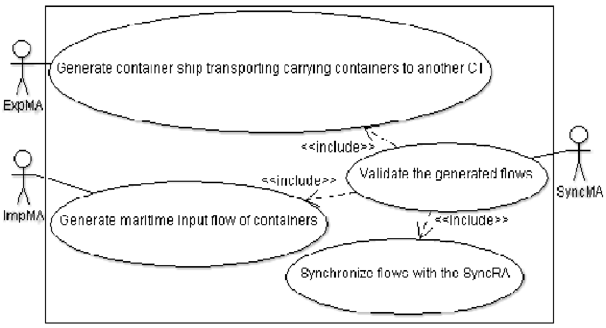


Figure 8: Use case diagram of interfacing subsystem with maritime transport providers

This subsystem consists of three agents:

- Export Maritime Agent (ExpMA) generates the container ships carrying containers, maritime output flow, to other seaports.
- Import Maritime Agent (ImpMA): generates the input flow of containers at the maritime interface by generating container ships transporting the generated containers to the CT.
- Synchronization Maritime Agent (SyncMA) validates the container flows generated by the two agents and ExpMA and ImpMA by contacting the SyncRA to interface with road transport providers to check the concordance between the input flow and output of the two interfaces of the CT.

By analogy with the interfacing subsystem with road transport providers this subsystem ensures the generation of input flow and output flow of containers in the CT maritime interface. The SyncMA is responsible for managing and synchronizing its operation with the SyncRA (figure9).

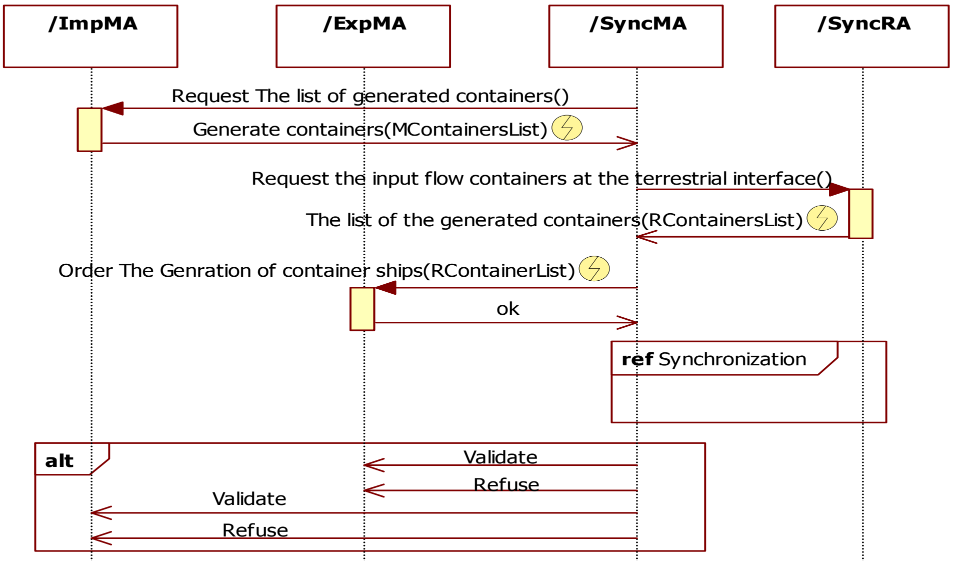


Figure9. AML Communicative sequence Diagram of the interfacing subsystem with road transport providers.

5.3. Representation subsystem

The representation subsystem reproduces the container handling operations at the CT. The purpose of this subsystem is to measure performance indicators in order to evaluate the impact of different strategies of risk management on the CT performance. Thus, to represent real operation of the CT, CTMS's agents are assimilated to the CT's actors and to the handling equipment (figure10).

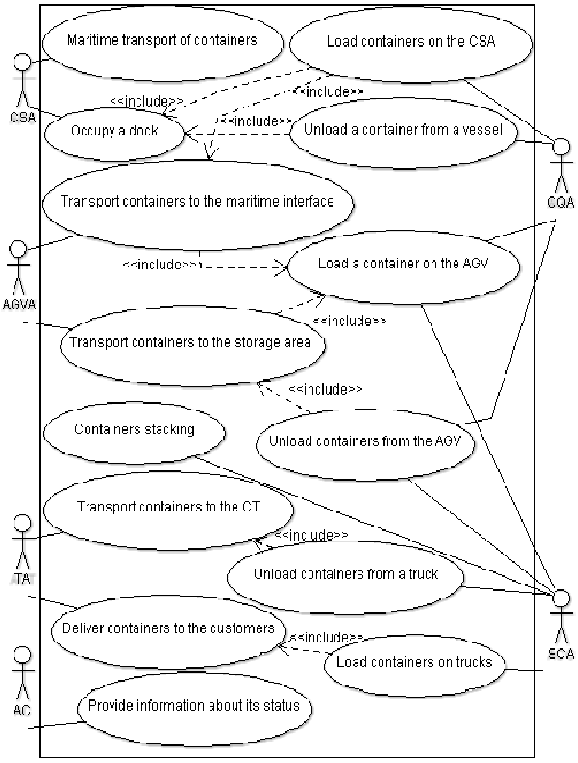


Figure 10: Use case diagram of the representation subsystem

The actors of this sub system are classified into two categories: the first one includes all active entities representing the handling equipment. The second category includes all the agents corresponding to containers generated at the two interfaces of the CT.

This subsystem consists of six kinds of agents:

- Container Ship Agent (CSA): represents the vessel carrying the containers, it is characterized by its capacity (TEUs), Size, arrival and departure date.
- Quay Crane Agent (QCA): load and unload containers from container ship, it is characterized by container handling time and its speed.
- Automated Guided Vehicle Agent (AGVA): transport containers between the container storage area and the maritime operations area. It is characterized by the container size that can move and its speed.
- Truck Agent (TA): transport container to the customers. This agent is characterized by the container size that it can carry.
- Straddle Carrier Agent (SCA): ensures stacking containers and at the storage area and it load and unload containers from trucks and AGVs. This agent is characterized by its speed and the size of containers.
- The Containers agents represent entities carrying information about the container; they are characterized by size, nature of goods, the quantity of the goods, origin of goods and the history of ports by which the containers were handled. The agent container updates its features by contacting the traceability system GOST.

The agents of this subsystem are controlled by the PA. It assigns handling tasks to agents to transport containers between the two interfaces of the CT. The following scenario describes the container transit process and its interactions with the other agents.

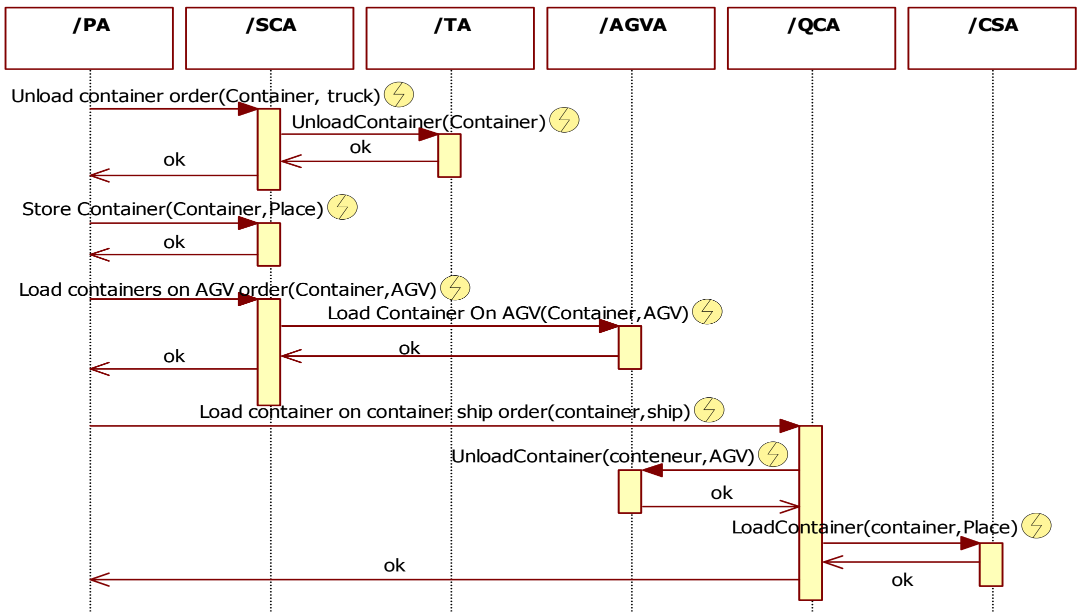


Figure 11: AML Communicative sequence Diagram of representation subsystem

5.4. Planning subsystem

Consists of a planner agent that allocates resources for handling containers. In addition, it ensures the allocation of containers storage places in CT (Figure 12). The PA pilots the operation of the representation subsystem and cooperates with the supervision subsystem in order to validate his decisions.

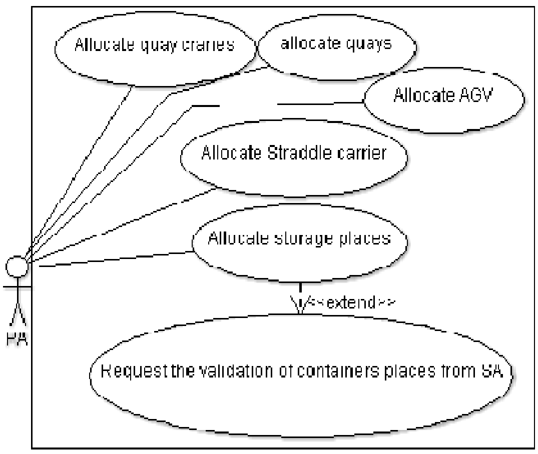


Figure 12: Use case diagram of the planning subsystem

5.5. Supervision subsystem

The supervision subsystem controls handling container operations in the CT and analyzes container information in order to target high risk containers that will be subject to inspection procedures by customs officials. First, the SA validates the storage location allocated by the PA and verifies the compliance with the rules of segregation between the classes of hazardous materials. In addition, it targets high-risk containers based on a case base containing information relating to the previous fraudulent containers detected during customs intervention (false declaration of goods, drug trafficking ...). Furthermore, this agent uses also a quantitative risk method for targeting risk containers based on the product of the probability that the container is fraudulent and the consequences of an incident relating to this event. The figure 13 describes the use cases of this subsystem.

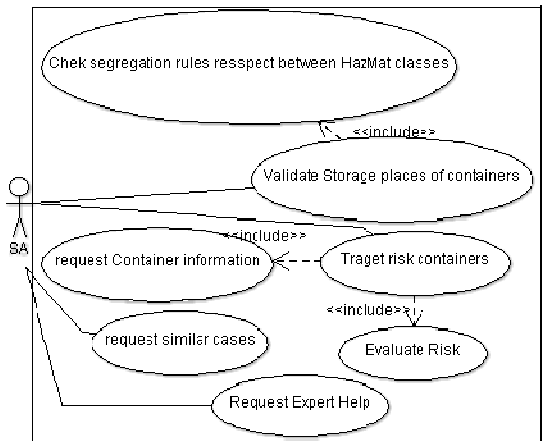


Figure 13: Use case diagram of the supervising subsystem

In order to prevent risk scenarios, SA analyze containers information and evaluate the risks. Furthermore, it validates PA decision especially in storage places allocation.

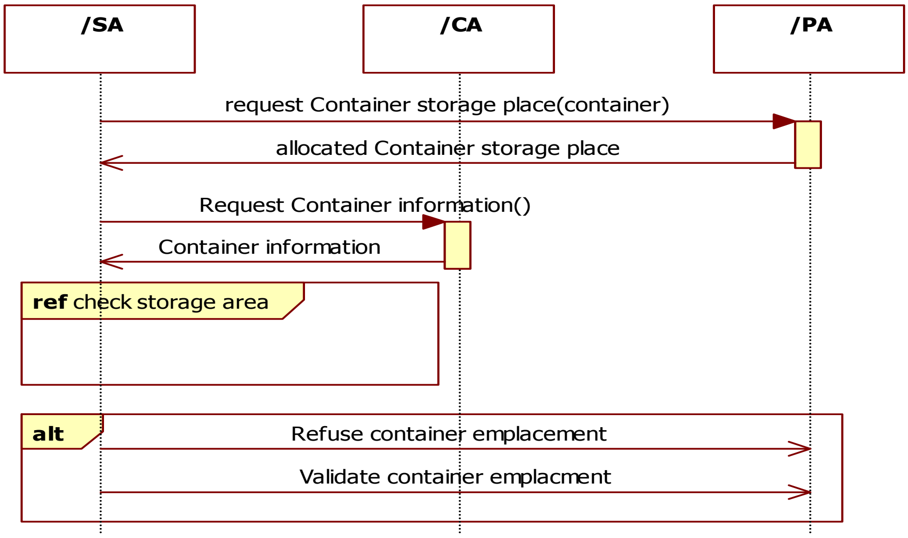


Figure 14: AML communicative sequence diagram of supervision subsystem

5.6. Learning Subsystem

Ensures archiving of previous fraudulent containers detected by the customs. Also, it stores information about risk scenarios. The main role of this subsystem is to provide SA with risk scenarios. The following figure presents the use case of this subsystem:

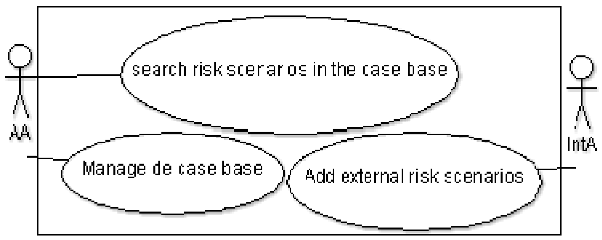


Figure15. Use case diagram of the learning subsystem

This subsystem is composed of two agents:

- Administrator Agent (AA): Manages the case base and stores new risk scenarios and information about risk containers detected by the system.
- Interface Agent (IntA): insures interfacing the learning subsystem with external.

6. CONCLUSION AND PERSPECTIVES

In this article we discussed the CT structure and the risks arising from the container handling operations and specially in the hazardous materials case. Then we proposed a CTMS model based on agent paradigm classified into several subsystems to reduce the complexity of the problem and to have a strong cohesion between the stakeholders operations. In addition we proposed the integration of risk management in the CTMS through the supervision subsystem preventing risk scenarios during handling operations.

In the future work, we will detail the supervision decision making process based on the decision rules provided by customs in order to target high risk containers. Furthermore, the implementation of the CTMS model using JAVA and the open source framework JADE (Java Agent DEvelopment Framework) is on progress.

The integration of risk management approaches in the simulation of the CT will allow the evaluation of the risk management strategies impact on the CT performance.

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WHATIF: A DECISION SUPPORT SYSTEM FOR PLANNING AND MANAGEMENT OF RAIL FREIGHT NETWORKS

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ABSTRACT
We present a Decision Support System to assist operators of rail freight networks in planning their activities and daily operations.
The DSS is interfaced with the information system of the rail freight company in order to access the most complete and up-to-date information on the location of rolling stock over the rail network, and the maintenance status of each wagon, on the current state of train circulation.
Given static information on the characteristics of the rolling stock fleet, and given the scheduled connections among terminals, an efficient rolling stock circulation plan, i.e. the routes of train compositions periodically connecting two or more terminals, is computed. Thanks to dynamically updated information and on the above mentioned circulation plan, a set of efficient train dispatching assignments, that is, the assignment of incoming train in a terminal to outgoing train rotations, is also obtained and proposed to the operational manager.

Keywords: rail freight network, decision support system, train circulation optimization, train dispatching.

1. INTRODUCTION

Managing a rail freight network at the continental scale is a complex business, not only for the sheer combinatorial complexity due to the large numbers of terminal relations to be served, and the dynamic complexity due to the temporal dimension of transports, but also for the extremely tight competition by road transport, which offers great flexibility, higher timeliness, and a competitive cost structure.

Yet, rail-based transport is often seen as the "way to go" and Europe in particular has been supporting rail-based transport with a number of policies, and targeted research projects over the years (Héritier et al. 2001, Marco Polo, European Commission, 2012). This is because of the ecological advantages of rail-based transport: less pollution, less particulate matter, more energy efficiency, and also less noise.

Rail-based transport is unfortunately fraught with a number of problems, the most relevant ones are the lack of an efficient network of intermodal terminals over most of Europe to allow for a quick and efficient modal change, and the lack of capacity on some key links. In particular, the high congestion observed on the European road network is also present in the rail network, and such traffic intensity makes the network more fragile and more susceptible to disruptions. As a consequence, the reliability of rail freight transport, which often has to yield to passengers transport, is at stake.

Rail freight companies face a difficult situation: they need to reduce their cost structure in order to compete with road-based transport, which has the great advantage of not externalizing its environmental costs (CO_2 taxes on fuel are negligible, as well as road freight transport taxes which are present only in some countries such as Germany, Austria and Switzerland).

While reducing costs, rail freight companies need to match a demand that is expected to grow by 80% by 2050 (European Commission, 2011) but at the same time can be highly volatile, especially during the current economical crisis. Furthermore, companies need to gain access to a rail network which has not been adequately developed during the past 50 years, at least since the 60s, when focus during the European economic boom shifted to road-based transport.

The logical consequence is that rail freight companies need to increase their efficiency, and this can be achieved by optimising the amount of rolling stock by a better planning of its usage and maintenance, and optimising the number of trains serving relationships among terminals.

In order to support rail freight companies in their operations, IDSIA has teamed with Hupac Intermodal SA, one of the leading European companies, in order to develop a suite of methods, algorithms and efficient and user friendly implementations to support the managers at various management levels: from strategic planning to operational management. Strategic planning involves the rolling stock circulation problem (Alfieri et al., 2006, Fioole et al., 2006) while operational management concerns online train dispatching (D'Ariano and Pranzo, 2009, Krasemann, 2012, Corman et al. 2011).

The result is an innovative decision support system (DSS) named WHATIF, which we describe in this paper.

In the next sections we first introduce the formalization of the problems we wanted to solve. We then show some examples of its use. Finally we discuss the first feedback obtained during the development phase, and we prospect future developments.

2. THE FORMALIZATION OF THE PROBLEM

The approach to the problem was inspired by the two level decision support system by Soncini et al. (1990), which decomposes a system management problem into two hierarchically structured problems: first a management problem is solved offline on a longer horizon, using a feedforward scheme; the solution of the above problem is then used as the reference value (set-point) for the solution of an online operational management problem, which is solved on a shorter time horizon. As shown in Figure 1, WHATIF DSS is structured in the following elements:

- WHATIF Composer (WCO): a software application that computes optimized train circulation plan. WCO can be used for strategic planning regarding the opportunity of opening new or closing existing relationships and by modifiying the schedule or the timetable. WCO solves the rolling stock circulation problem as shown in Section 2.1.
- WHATIF Planner (WPL): a software application for the operational dispatching of trains from terminal to terminal. WPL, also using the WHATIF simulator briefly described below, solves the train dispatching problem, as shown in Section 2.2.
- WHATIF Simulator: given the train dispatching decisions, the impacts and future evolution of the network state are projected in the near future.

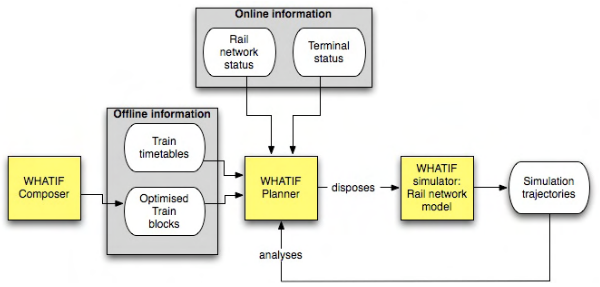

Figure 1: The logical structure of the WHATIF DSS and its modules.

In our knowledge, this is the first time such an integrated approach has been adopted in the context of rail freight planning and management. Previous developments of DSSs to the rail domain were mostly focused either on train rescheduling at the rail network operational management level or on terminal management issues (e.g. yard management). On the other hand, WHATIF DSS is directly aimed at and focuses on the business model of the intermodal transport company.

2.1. The Rolling Stock Circulation Problem

In the context of the rail freight network problem, the offline management problem is solved to compute the optimized train circulation, using as inputs the total availability of rolling stock and the timetables which specify the availability of a connection between two or more terminals during a specified time period. Currently, timetables are purchased by the freight operator from network operators such as DB in Germany, RFI in Italy, SBB in Switzerland. We refer the reader to Caprara et al. (2002), Peeters (2003) and Cacchiani (2007) for the mathematical modeling and solution procedures to the planning of optimal timetables. Timetables are purchased according to forecasts of transport demand. Unfortunately there are many constraints on the availability of timetables, especially passenger transport and the limited capacity for infrastructure, and therefore they cannot be considered a decisional variable for the rail freight company. Therefore, we consider the timetable as given.

The timetable is specified as a set of services S between one or more terminals. We denote by o_s^k and d_s^k the k-th origin and destination of service $s \in S$, respectively. With each service s are associated departure time a_s^k and arrival time b_s^k at origin and destination terminals, respectively. Departure and arrival times include the time necessary to load and unload freight and to perform the necessary security checks.

The rolling stock is classified into wagon types, denoted by the set H, having specific characteristics, i.e., the ability of carrying different cargo types (different classes of freight, from containers to semi-trailers) and specific length. In order to harmonize the circulation in the network and to reduce the operational costs of frequent shunting operations, freight transportation companies classify services according to recurrent demand patterns referred as families of composition or train units. Each pattern $p \in P$ is defined by the number of modules of each wagon type composing the pattern and denoted by q_p^h. The estimated traffic demand on service s is therefore converted into a specific demand for pattern q_s^p.

We represent the rolling stock circulation problem as a multi-commodity flow with additional constraints on a time-space network $G = (N, A)$. The network is made of nodes $n \in N$, which represent events (either departures or arrivals) at specific terminals and arcs $a \in A$ which represent either travel durations when connecting nodes at different terminals or waiting times when connecting nodes at the same terminal.

Connections must be feasible, i.e., $a_s^k \geq b_s^k \; \forall \; k \in K, \forall \; s \in S$.

The definition of sets, parameters and variables used to model the Rolling Stock Circulation (RSC) are provided in Tables (1)-(3).

Table 1: Sets for the RSC model.

Description	*Set*
Set of terminals (nodes) indexed by n	N
Set of services indexed by s	S
Set of available patterns indexed by p	P
Ordered set of all events on the time-space network, indexed by t	T
Set of nodes in the time-space network	$V(n,t)$
Set of inbound services to node (n,t)	$I(n,t)$
Set of outbound services from node (n,t)	$O(n,t)$

Table 2: Parameters for RSC model.

Description	*Parameter*
Demand of pattern p in service s	q_s^p
Number of available patterns p	N^p
The first event in the time line at terminal n	$minE_n$
The last event in the time line at terminal n	$maxE_n$

Table 3: Decision variables for RSC model.

Description	*Variable*
Number of patterns p on service s	x_s^p
Number of patterns p at terminal n immediately after time t	y_{n,t^+}^p
Number of patterns p at terminal n immediately before time t	y_{n,t^-}^p

The RSC model is defined as follows:

$$min \sum_{n \in N, p \in P} y_{n,minE_n^-}^p \quad (1)$$

$$s.t. \; x_s^p \geq q_s^p \; \forall s \in S, \forall p \in P \quad (2)$$

$$y_{n,t^-}^p + \sum_{s \in I(n,t)} x_s^p = y_{n,t^+}^p + \sum_{s \in O(n,t)} x_s^p \; \forall (n,t) \in V, p \in P \quad (3)$$

$$y_{n,minE_n^-}^p = y_{n,maxE_n^+}^p \; \forall n \in N, p \in P \quad (4)$$

$$x_s^p \in \mathbb{Z}^+ \; \forall s \in S, p \in P \quad (5)$$

$$y_{n,t}^p \geq 0 \; \forall (n,t) \in V, p \in P \quad (6)$$

Objective function (1) minimizes the number of necessary patterns to perform the schedule. If $\sum_{n \in N} y_{n,minE_n^-}^p \leq N^p \; \forall p \in P$, there exist a feasible and optimal rolling stock circulation plan. Otherwise, $N^p - \sum_{n \in N} y_{n,minE_n^-}^p$ represents the number of patterns p necessary to fulfill the schedule. In such case, the company has to rent additional wagons from third parties. Constraints (2) impose that each service must be formed by an appropriate amount of patterns. Constraints (3) are flow conservation constraints. Constraints (4) are optional. When imposed, they induce a cyclic rolling stock circulation plan. Finally, bounds on variables are defined by constraints (5)-(6). The model is solved using a general purpose MILP solver.

Currently, decision makers planning for rolling stock circulation at our industrial partner use a FIFO policy, i.e., at each terminal, each incoming train is associated with the earliest outgoing train. Under this policy, the rolling stock circulation can be solved in polynomial time by a dynamic programming algorithm.

2.2. The Dispatching Problem

At the operational level, the role of the train dispatchers is to maintain the train circulation plan. In each terminal the dispatcher sees a number of incoming trains, which need to be unloaded and then reassigned to one of the outgoing train compositions. A train composition is a set of wagons with specific characteristics with respect to the load they can carry. According to the specific terminal relationship, different compositions will be used.

Had everything been running perfectly, the same train compositions would circulate connecting the same terminals, according to the circulation plan.

This is unfortunately impossible due to unexpected disturbances on the rail network (e.g. breakdowns), strikes and breakdowns in terminals, and delays. The dispatcher needs therefore assistance in making the best decisions in order to stick as much as possible to the train circulation plan, which guarantees the most efficient use of the fleet. Whenever a train is rerouted on a different relationship, its composition might be less than ideal, and therefore a compromise needs to be made.

The profitability indicator measures the length of the incoming train with respect to the desired length of the outgoing train. Train length is an aggregated and widely used performance criterion in railway freight transportation. Mathematically, let $\sum_{p \in P} len(q_{in}^p)$ be the total length of the patterns composing the incoming train in. Then the profitability indicator is defined as:

$$I_{pr} = \min\left\{1, \sum_{p \in P} len(q_{in}^p)/len(q_{out}^p)\right\}$$

Two conformity indicators measure the compliance of wagon patterns circulating on the incoming train with respect to the desired wagon patterns of the outgoing train. We remark that some wagon types are able to accommodate the cargo type of other wagon types, even if they are not specifically conceived for it. Therefore, it is possible to define a compatibility indicator between two different patterns. Mathematically, we define the following conformity indicators:

$$I_{con} = \frac{\sum_{p \in P} \frac{\min\{q_{in}^p, q_{out}^p\}}{q_{out}^p}}{|P|}$$

For each pattern of the incoming train not accounted in the conformity indicator, we compute the compatibility with each pattern of the outgoing train and retain the maximum. We remove the pattern pair and iterate the process. We denote the compatibility computed as above by I_{com}.

The final performance indicator is used to estimate the ability of a given relationship to "absorb" the accumulated delay of the incoming train. This indicator, named the delay risk indicator I_{dr} is computed using a stochastic approach based a large set of historical data.

Essentially, we estimate the delay propagation as follows. Let r_0 be an arriving train with delay δ_0 and $\{r_1, \dots, r_m\}$ the train sequence that follows train r_0. The propagation of the delay δ_0 on the sequence $\{r_1, \dots, r_m\}$ can be modeled by a stochastic sequence $\{X_k\}_{k=0,\dots,m}$ where each X_k is a random variable describing the state of the delay at the arrival of train r_k. In our model delays are classified in 5 clusters $\{C_0, \dots, C_4\}$ usually adopted by the company: cluster C_0 means no delay, C_1 a delay within 1 hour, C_2 between 1 and 3 hours, C_3 between 3 and 6 hours and C_4 indicates a delay over 6 hours. Each random variable X_k can assume any of the 5 delay states $\{0, \dots, 4\}$ corresponding to the 5 delay clusters. In this context it is reasonable to assume that the delay state at the time instant $k + 1$ depends only on the current delay state at time instant k and not on previous delay states. Therefore the stochastic sequence $\{X_k\}_{k=0,\dots,m}$ can be classified as a discrete-time Markov chain. The key idea of our approach is to extrapolate the transition probabilities $h_{ij}(k) = P[X_{k+1} = j \mid X_k = i]$ of the delay propagation Markov chain from the historical delay data set. In other terms we define the transition probabilities in such a way, that the Markov chains generated are consistent with the real delay propagation patterns observed in the past. In order to generate the transition matrices $H(k) = [h_{ij}(k)]$ we focused on the delay propagation pattern of each couple of consecutive trains $\{r_k, r_{k+1}\}$ in the chain. More precisely, we analyzed the delay data of 20'000 compositions circulated on the Hupac transportation network during a period of 6 months and we aggregated them per clusters and per couples of consecutive relations. Then for each couple of relations we calculated a transition matrix based on the historical data set. As an example we report in Table 4 the transition matrix of the couple of relations {BUS2-KOEL, KOEL-BUS2} based on 166 samples.

Table 4: Transition matrix of the couple of relations {BUS2-KOEL, KOEL-BUS2}

	C0	C1	C2	C3	C4
C0	0.39	0.43	0.10	0.04	0.04
C1	0.34	0.16	0.34	0.05	0.11
C2	0.36	0.35	0.18	0.04	0.07
C3	0.56	0.22	0.11	0.00	0.11
C4	0.32	0.09	0.27	0.14	0.18

For example, we read from Table 4 that 39% of the trains arrived on time on the relation BUS2-KOEL, came back on time to BUS2, while 43% of the trains on time the way there report a delay in cluster C_1 on the way back. The transition matrices of the couples of consecutive relations enable us to forecast the risk of delays after a given sequence of relations. In fact, given an initial delay distribution $d(0)$ and a sequence of transition matrices $\{H(k)\}_{k=0,\dots,m-1}$, the forecasted delay distribution $d(m)$ after the train sequence can be calculated on the basis of the Chapman-Kolmogorov equation as

$$d(m) = (\prod_{k=0}^{m-1} H(k))^T \cdot d(0) .$$

As an example, let's consider a train with a delay of 80 minutes on the relation BUS2-KOEL, which is assigned to the rotation {KOEL-BUS2, BUS2-KOEL}. What kind of delay distribution might be expected after the rotation? By means of the transition matrices of the 2 couples of relations involved we obtain the output distribution $d(2) = [0.43, 0.21, 0.19, 0.05, 0.12]$. This result means that, according to the delay evolution observed in similar situations in the past, we can expect that the train will absorb the present delay with a probability of 43%, whereas a delay of cluster C_1 can be expected with a probability of 21%, and so on.

In order to compare the quality of the assignment of a train t_0 to different possible rotations it is necessary to reduce the information of the output distribution $d(m)$ to a numerical indicator that can be easily interpreted. The most straightforward indicator of the delay propagation is the expected value of the output distribution $d(m)$. In the previous example we obtain an expected value of 1.21, which means that in average we might expect an output delay of cluster C_1. For each assignment selected by the dispatcher WHATIF calculates a normalized delay risk indicator I_{dr} which depends on the sequence of trains $\{r_k\}$ and on the initial delay δ_0

In summary, we compute the above described performance indicators for every feasible pair of incoming and outgoing trains at a terminal and we formulate the dispatching problem as a maximum weight matching on a bipartite graph. Let $G = (V, E)$ be a bipartite graph, i.e. a graph in which there exists a partition X, Y such that $V = X \cup Y$, $X \cap Y = \emptyset$ and $E \subseteq X{\times}Y$. X represents the set of incoming trains at every station and Y represents the set of rotations originating at some station. An edge $e \in E$ exists between $x \in X$ and $y \in Y$, if it is feasible to cover rotation y using the composition running on train x. The feasibility of the assignment is determined by time-space constraints, i.e., the two services must be incident at the same terminal and the incoming train must be fully unload before the expected loading time of the outgoing train. Additional feasibility constraints are imposed by dispatchers in order to improve the performances of the assignment. In particular, referring to previously introduced performance indicators, lower thresholds on performance indicators are set, we refer to these thresholds as $\tilde{I}_l \ \forall l \in L$, with $L = \{pr, con, com, dr\}$. Therefore, an assignment is considered feasible if $I_l(e) \geq \tilde{I}_l \ \forall l \in L$. We associate a weight with every edge of the graph $e \in E$. The weight is computed using a convex combination of performance indicators, i.e., $w(e) = \sum_{l \in L} \alpha_l \cdot I_l(e)$, for any $\alpha_l \ l \in L| \sum_{l \in L} \alpha_l = 1$.

A matching is defined as a subset of edges $M \subseteq E$ such that $\forall x \in X$ at most one edge in M is incident to x. The size of a matching is $|M|$. The weight of the matching is computed as the sum of the weights of edges in the matching, i.e., $w(M) = \sum_{e \in M} w(e)$. A matching M is a maximum weight matching if there is no other matching M' such that $w(M') > w(M)$. We recall that a max-weight matching is perfect, i.e., a matching in which every vertex is adjacent to some edge in M. The maximum weight matching on bipartite graphs is a polynomially solvable problem. We implemented the algorithm by Kuhn-Munkres also known as the Hungarian algorithm which runs in $O(n^3)$.

We remark that if $|X| \neq |Y|$ we create dummy vertices x' or y' and dummy edges e' with $w(e') = 0$. When dummy vertices are selected for being part of the maximum weight matching, the associated non-dummy vertices are left unmatched in the solution proposed to the dispatcher.

In order to provide additional dispatching opportunities to the operator, we iteratively solve the maximum weight matching removing the set of optimal edges from the initial set, i.e., $E \Leftarrow E \setminus M$ for a fixed number of iterations J. Let M^j be the maximum weight matching obtained at iteration $j \in \{0..J\}$. Then, M^0 is the optimal matching while M^i with $i \in \{1..J\}$ represent alternative options.

Most of the times, train assignments are chosen following best practices which are not encoded in the input data. During execution, WHATIF collects the chosen disposition alternative among a set of feasible ones. Based on this data, we have embedded in WHATIF a statistical model, which considers the most frequent assignments matching the current network status. In the maximum weight matching we consider statistically relevant alternatives with a positive contribution to the edge weight.

3. EXAMPLES OF USE

Hupac Intermodal SA (www.hupac.ch) operates more than 100 trains a day at a continental scale (see Figure 2) with regular connections to the Far East and the Asian continent. Hupac served more than 700.000 road consignments in 2011.

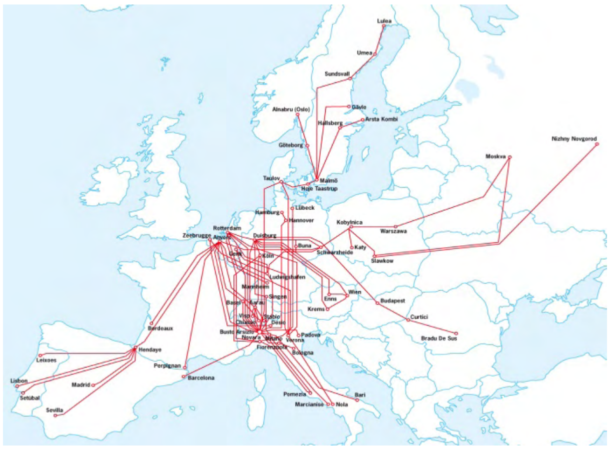

Figure 2: The continental network of Hupac Intermodal SA.

We illustrate the typical use of WHATIF Composer using a simple example. We consider the circulation plan between the terminals of Busto Arsizio (BUS2), Hamburg (HAMB) and Hannover (HANN) as shown in Figure 3. In a typical week, 6 trains circulate from north to south and vice versa. Given the timetable, WCO computes the needed rotations. (4 in the example). Using WCO, the network planner is able to evaluate schedule variations. For example, the service department detected a systematic lack of demand on Thursdays, the network planner can evaluate the effect of suppressing Thursday trains. For this network structure, suppressing the Thursday train does not produce any reduction in the number of requested compositions. Therefore, it is still convenient for Hupac to keep the Thursday train.

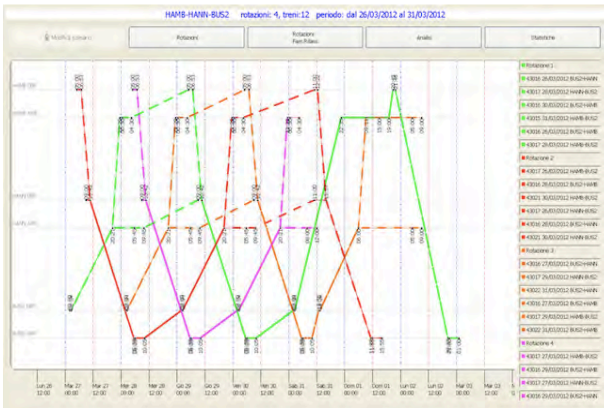

Figure 3: An illustration of the result of WHATIF Composer over a multi-terminal relationship (BUS2-HAMB/HANN) over a typical week: 12 trains are served with the rotation of 4 compositions.

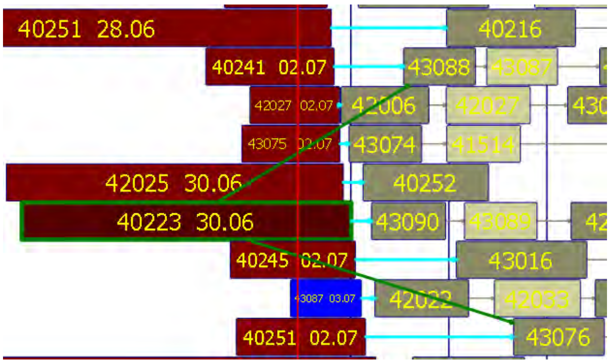

Figure 4: An illustration of the result of WHATIF Planner on a subset of trains heading to BUS2.

In Figure 4, we illustrate one of the uses of WPL. The illustration reports a subset of trains heading to Busto Arsizio terminal (BUS2, Hupac's main hub). We notice incoming trains on the left of the picture and train circulations originating in BUS2 on the right. Optimal assignments (M^0) computed by WPL are reported in light blue and are always visible. Alternative options are shown on demand to the dispatcher. In Figure 4, for example, alternative assignments for incoming train 40223 are reported in green. Alternative options can be shown for outgoing trains as well. Performance indicators for the optimal and alternative options are reported in a dedicated dialog (see Figure 5).

Figure 5. Report on performance indicators (in Italian). "Conf" is the conformity indicator, "Comp" is the compatibility indicator, "Lung" is the profitability indicator and finally "Rit" is the delay risk indicator, as described in Section 2.

4. CONCLUSIONS

The WHATIF decision support system is currently being deployed at Hupac Intermodal SA. The first feedback is encouraging, as it allows managers to solve their task in a more rapid and effective way. In particular, WHATIF is proving itself as a valuable tool for the strategic planning of commercial routes: testing whether a new connection is economically and technically viable can be done in a matter of minutes, against a previous effort of many hours. WHATIF is also demonstrating its validity as a support tool for dispatching trains from the wide network of terminals served by Hupac. The train dispatcher can easily consult the DSS to both easily access facts and figures on key train indicators, and also ask the DSS for support in making informed decisions.

ACKNOWLEDGMENTS

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ECONOMIC ASSESSMENT FOR A RFID APPLICATION IN TRANSFUSION MEDICINE

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ABSTRACT

Aim of the study is to evaluate economical feasibility of a Transfusion Medicine RFId application, which was studied in order to enhance patient safety and in order to improve blood inventory management processes.

A reverse engineering of processes was performed through Flow Charts and Activity Forms and a RFId-based processes re-engineering has been designed in order to reduce criticalities. Then a Return on Safety assessment was performed through a RFId-enabled processes FMECA and through Key Performance Indexes (KPI) design.

Finally a cost-revenues analysis was performed in order to verify the investment economic sustainability. Using HF and UHF RFID technology was considered, and a multi-scenario economic analysis was performed.

This pointed out that Payback Periods, related to the two technology choices, are comparable only if project implementation allows a waste reduction higher than 3.5%. The study also showed that economic benefits are maximized if project application is pervasive.

Keywords: RFID, economic assessment, transfusion medicine, risk management

1. INTRODUCTION

The health care industry is currently growing very fast and it is also facing many challenges from the increasingly competitive and globalized business environment.

In order to stay competitive, businesses in the health care industry have applied new technologies to manage patients, personnel, and inventory to streamline the efficiencies and effectiveness of business functions (Chong and Chan 2012). The potential of Radio Frequency IDentification (RFID) technology within health care environments has been assessed by several studies, showing positive effects on patient safety and logistics concerning patients and medical products (Van der Togt et al. 2011).

Improving operational efficiency through RFID technology, allows Heath care facilities to gain a competitive advantage over their competitors (Chong and Chan 2012).

Nevertheless, prior experiences show that RFID systems have not been designed and tested in response to the particular needs of health care settings might introduce new risks. Although the high employment flexibility of RFID technology, each application has to be carefully studied in order to achieve estimated project results and investment economic justification.

Even though the main goal of health care investments is to increase the quality of service provided to patients, economic analysis is necessary to provide an economic justification of proposed investment. Particularly, a RFID application project has a specific complexity because of variety of components which can be chosen for the system design. RFID systems differ in operative frequencies, transponder energy supply, complexity of chips mounted on tags, presence of additional components such as sensors, memory capacity ecc.

These characteristics are related to technical specifications (reading distances, volume of multiple read etc..), and to considerable cost differences for the systems implementation (Talone and Russo 2006).

The present work is allocated in this context. Its aim is to assess the economical feasibility of a RFID application in Transfusion Medicine, which was studied in order to enhance patient safety (Borelli et al. 2010) and in order to improve blood inventory management processes (Orrù et al. 2010).

Transfusion Service is one of the healthcare areas with high intervention potential. As a matter of fact clinical risk related to transfusion medicine is still a very important topic within Healthcare systems. ABO incompatible transfusions data frequency is considerable: Germany 1:36000; USA (New York) 1:38000; France 1:135207; Ireland 1:71428 (Ahrens et al. 2005), in case of Acute Haemolitic reaction, deadly consequences for patients may occur in 10% of cases (De Sanctis, Lucentini et al. 2004). Post transfusion viral transmission probability is about 1:1900000 for HIV and 1:1600000 for HCV (Goodnough 2003).

It's important to note that about 50% of United Kingdom SHOT (Serious Hazards of Transfusion) 2011 reports are caused by human error, RFId systems aim to delete them by introducing safer identification devices and procedures.

Transfusion medicine is one of the most important intervention areas because blood components are high added value assets, so a more efficient management of them may generate important economic advantages.

Furthermore, the specific blood need of Sardinia Island people are outstanding: in view of the very high proportion of thalassemic patients, it is the most High-level in Italy (64 packed red blood cells units/1000 inhabitants, while the national average is 42) (Istituto Superiore della Sanità 2008).

2. RFID PROJECT

The project has been developed at Blood Transfusion Centre (BTC) of AOB Hospital in Cagliari (Sardinia Island, Italy). The Blood Transfusion Center and two of the most important operative units of the Hospital, Transplant Unit and Brain surgery unit, were involved. The main study steps are summarized below.

2.1 Analysis step

In the first part of the study, a reverse engineering of present processes (As-is) was performed, by means of visits and operator interviews in order to map processes, to define information and material flows and to analyze infrastructure and technology status. As-Is analysis was performed through two tools : Flow Charts and Activity Forms.

Criticalities and process error sources were put in evidence through a Failure Mode Effects and Criticalities Analysis (FMECA) in order to suggest suitable actions for process refinement. Through Risk Priority Index (RPI) definition and through a bar chart set and a variable threshold ABC analysis, possible failure modes were studied and classified.

FMECA showed that most critical activities are carried out inside Unit Wards; particularly highest RPI values were measured in case of human errors.

2.2 Synthesis Step

In the second part of the study, an RFId-based processes re-engineering (To-Be Model) has been designed in order to reduce criticalities and to improve Transfusion Medicine service performances. Synthesis stage was divided in two different parts which are mutually complementary.

The first part regarded "Transfusion Loop" processes (Borelli et al. 2010), while the second one regarded all processes from Blood Donation to final storage (Orrù et al. 2010). Their implementation would be a new system model for whole Blood Chain process management. (Borelli et al. 2011).

Process re-engineering stage was formalized by creating more than 20 new flow charts and the related Activity Forms.

2.3 Return on Safety (ROS) assessment

A Return on Safety (ROS) assessment was performed through a RFId-enabled processes FMECA and through Key Performance Indexes (KPI) design.

FMECA pointed out that human errors in manual operations are still the most important. Particularly clinical activities (including patient treatment, manual blood testing etc.) are fewer, than other general activities (writing, material handling etc.).

Three KPI were used in order to evaluate "ex ante" the RFId project main goal achievement i.e. clinical risk reduction in Blood Chain Processes.

ROS assessment pointed out an appreciable clinical risk reduction within the whole Blood Chain (figure 1) and a not considerable variation of activities amount.

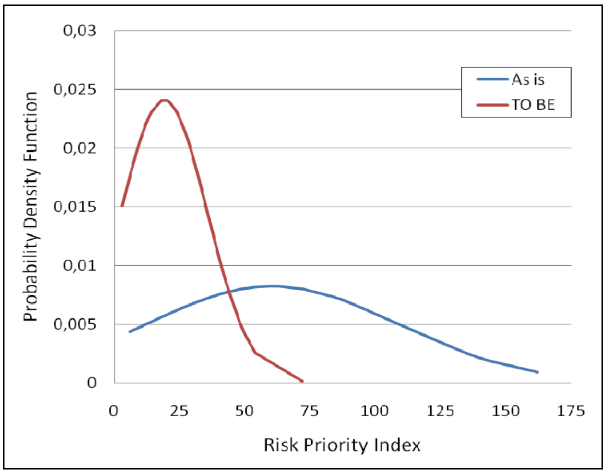

Figure 1. Comparison between AS-IS and TO-BE Normal Distribution of RPI values

3. ECONOMIC ASSESSMENT

After ROS assessment a cost-revenues analysis was performed in order to check the investment economic sustainability.

Cost-revenues type economic analysis was chosen, because it considers cash revenues only, ignoring other kinds of benefit such as image return, legal disputes missed costs ecc. These benefits, even though generate revenue, require strong hypotheses to perform their monetization, so it was decided to consider them in a next study step i.e. the cost-benefits analysis.

The economic analysis was carried out through 6 spreadsheets development. One of them is a general data and information collecting about the case study Hospital, one is related to project development costs and process management costs, two are related to revenues setting out, and finally, the last two are used to process data and to show the analysis results.

3.1. General Data collection

As a first step, general data about the whole hospital and Operative Units were collected in a worksheet called "Context Data", in order to have a detailed frame of the case study. This kind of data were set as variable parameters in order to check the analysis results trend and to have the possibility to apply the computing model to other healthcare facility contexts. For instance receptive capacity data, medical and non-medical personnel amount, all blood components transfusion statistics, wastes statistics (due to over date and other general causes) were collected. Part of this data were directly provided by AOB Healthcare facility, while remaining data were obtained by "Regione Sardegna" official documents (Regione Autonoma della Sardegna 2008). Available Blood donation and blood components assignation statistical data were related to Cagliari large area, so they were treated and scaled in order to estimate AOB Healthcare facility only data.

Furthermore, macro-process cycle times were collected in the Context Data worksheet. They had been extracted by a time and methods analysis which had involved all Blood Transfusion center processes, and all unit ward transfusion processes. All activities, regarding both human actions and automatized processes (automatic screenings, blood units or samples centrifugation etc.) were timed; recorded times which referred to simultaneous performing of multiple cycles or requests, were set out in unit time form.

3.2. Cost Computing

The second step consisted in cost computing, which was carried out splitting plant costs and operating costs.

As for cost computing a market analysis was made, and advice was sought from two of the most important Italian suppliers and developers of RFID systems, which also provided purchasing official estimates.

Costs computing was carried out referring to eight distinct design scenarios. The use of two types of RFID technology, HF 13.56 MHz and UHF 865-868 MHz, was hypothesized. Furthermore, since the research project should be developed in the Hospital following several steps, partial applicative scenarios were considered. According to the "To Be Model", First level application and Second level application were separately analyzed because they can be developed independently and they have different and complementary goals.

Each technology option was indeed studied both in case of Transfusion Loop only (processes ranging from patient accommodation to blood component transfusion) and all blood chain processes (acceptance, testing, treatment and storage of donated blood) application.

The last distinction was related to the type of tracked items: packed red blood cells (RBC) only (the most used blood component in transfusion medicine), and all blood components tracking were separately studied.

Considering partial applicative scenarios will be useful because, during experimental development phase of the project, it provides economic framework by showing minimum project expansion level that are sufficient to achieve a positive return of the investment.

3.2.1. Plant Costs

Main plant costs were hardware and software purchasing, network infrastructure adaptation or realization, and personnel training about the new system and new procedures. Plant costing was carried out referring to two design scenarios: the use of two types of RFID technology, i.e. HF 13.56 MHz and UHF 865-868 MHz, was hypothesized. Total plant costs are quite similar: UHF costs are about 1.5% higher than HF costs; particularly Hardware costs are the only element that differ, while software development and infrastructure costs (for instance Wi-Fi network deployment) were considered the same for the two technologies.

3.3. Operating Costs

Main operating costs were related to tag purchasing. The difference between the plant cost installation was almost limited, while UHF tags average cost is about 30-40% lower than HF tag cost. This difference greatly affects the technology choice.

In addition, maintenance costs related to hardware, network infrastructure technology and software were computed as operating costs. Maintenance costs were calculated as a fraction (1% - 2%) of each item cost.

3.4. Revenues

Revenues directly obtained by plant using were all intended as missed disbursement. They derive from two main kind of improvements: productivity improvement due to cycle time reduction, and quality improvement due to wastes reduction and more efficient blood inventory management.

3.4.1. Productivity

Economic benefits obtained by Transfusion Service productivity improving were quantified as follow.

For each macro-process, project-status cycle times were estimated basing on the related flow chart and activity forms. Then, differences between present-status and project-status cycle times were computed. Both positive and negative differences were obtained, because re-engineering caused streamlining of some process while integration of some others through additional activities that aim to improve safety level. Hospital staff pay scale were considered, and medium salaries were converted in €/min; then economic benefits for cycle (for instance a single blood unit treated, or a single request treated etc.) were evaluated and, considering the number of cycles per year, annual economic benefits were computed. This analysis was performed considering both Transfusion loop only application and all blood chain process application, and considering separately RBC units only and all blood components traceability. These scenarios differ in cycle number.

Table1. Economic benefits due to productivity improving of Blood components assignation process.

Blood Assignation			
	Cycle Time Gain [min]	Benefits [€/Cycle]	Benefits [€/year]
Physician	0.05	0.02	940.60
Nurses	0.25	0.06	2939.40
Lab Technicians	0.20	0.05	2351.50
Auxiliaries	0.00	0.00	0.00

3.4.2. Quality

Then missed disbursement due to the expected decreasing of discarded blood units were quantified. This analysis step was carried out by distinguishing two scenarios: packed red cells only tracking and all blood components tracking.

Each blood component unit cost was obtained by official documents (Regione Sicilia 2006) and they were updated to year 2011 through appreciation coefficient equal to 1.0974, according to the National Institute for Statistics (ISTAT) official tables. Each "saved" blood unit was also associated to a consumables and disposable medical devices saving.

Due to the difficulty in precisely estimating waste reduction, this was set as a parameter, and the range between 3% and 4% was identified as possible variation range.

4. DATA ELABORATION

The economic analysis main parameters were summarized in both analytical and graphical form for each technological and operational scenario, and they were reported in two specific worksheets, the first one related to first level application only, and the second related to all blood chain processes application.

Partial cash flows were computed for each cost and revenue worksheet, while total cash flows were reported in data elaboration worksheets, considering a 25 year investment horizon. The cash flows were updated assuming a 5% discount rate, because using of pubblic funds for project development was assumed.

Traditional financial indicators for investment evaluation, such as Net Present Value (NPV) and Pay Back Period (PBP) were then calculated and reported both in analytic and graphic form.

Furthermore a differential analysis was performed for each studied scenario, in order to compare HF and UHF technology investments. UHF technology is marked by plant cost higher than HF while operating costs lower than HF, so differential analysis aims to point out minimum periods for which UHF investment would be more cost-effective than HF investment.

5. SENSITIVITY ANALYSIS

First study steps showed that process re-engineering causes an overall slightly reduction of process amount and process cycle times, caused by the balance between process streamlining and integration (Borelli et al. 2011). The influence of productivity enhancement on positive cash flows is quite low: about 4.3% of total estimated annual revenues. Due to the high unit cost of blood components, waste reduction is the key parameter which substantially conditions positive cash flows trend.

Due to the difficulty in precisely estimating annual waste reduction related to project development, a sensitivity analysis was carried out in order to monitor the PBP trend to waste reduction variation within the range limits (3-4%) (Figure 2).

Exact quantification of this parameter can be obtained during the pilot plant testing phase in the healthcare facility, through the process data collection during a window period (at least six months). This data may be screened and compared to the present economic analysis, in order to provide an important decision support in suitable technology choice.

The sensitivity analysis was performed referring to the global extension scenario i.e. all blood chain processes application and all blood components tracking.

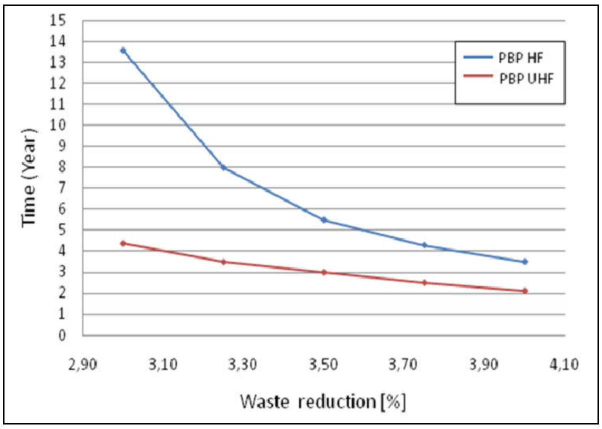

Figure 2. Sensitivity Analysis.

6. RESULTS

6.1. Global Application Scenario

Analysis results was performed by assuming waste reduction parameter equal to 3%, i.e. the variation range lower limit.

Analysis results show clearly that the investment is economically sustainable in case of project global application, i.e. including all blood components traceability and all blood transfusion chain processes.

Furthermore analysis points out that among operating costs, tag purchasing is still the most important aspect for the project development. Cost difference between UHF and HF technology, cause significant PBP difference (about 13.8 years using HF tags, about 4.5 using UHF tags). This is also highlighted by differential analysis.

6.2. Partial Application Scenario

As for partial application scenarios which were analyzed, main results are the following.

In case of Transfusion loop only application, that is a possible pilot plant opening configuration, cash flows are always negative, so the investment is not justified from a strictly financial point of view. Anyway, the almost complete elimination of clinical risk related to ABO incompatible transfusions, and the consequent patients and staff safety increase, may generate benefits that could be sufficient for the implementation.

The only partial application scenario where the investment PBP is within time horizon (PBP=8.5 years), is the case of all blood chain processes application for RBC only traceability, using UHF technology.

6.3. Sensitivity Analysis

Sensitivity analysis pointed out that the two PBP, related to the different technology choices, are comparable only if project implementation allows a waste reduction higher than 3.5%. Assuming a 3.5% waste reduction, PBP related to UHF system is about 3 years while PBP related to HF is slightly higher than 5 years.

In the optimistic case of 4% reduction, the two measured PBP further approach, till they arrive at about 18 months mutual difference.

On the contrary assuming waste reduction values below the 3.5% threshold, the payback time difference between the two technologies increases dramatically: UHF technology is rather more convenient.

Assuming a waste reduction equal to 3%, the PBP relative difference is about 9 years (PBP related to UHF is 4.5 years while PBP related to HF is 13.8 years).

7. CONCLUSIONS

In this paper, a cost-revenue economic analysis for investment evaluation related to a RFID project in Transfusion Medicine was performed.

Two main technology alternatives and several applicative scenarios which range from a pilot plant configuration to a project global development were considered.

The study showed that economic benefits are maximized if the project application is pervasive. Therefore RFID system in the healthcare should not be limited to transfusion traceability, but that should be a start-up step, which should lead to platform development in order to solve many hospital logistic problems. In this way return on investment economic parameters would be optimized, and the whole Healthcare facility performances would be enhanced.

Economic and sensitivity analysis results pointed out that UHF technology employment would ensure profitable pay back periods, even if waste reduction parameter, measured during experimental phase, would be below the 3.5% critical threshold.

Currently only the use of ISO/IEC 18000-3 mode 1 13.56 MHz RFID tags has been accepted by the United States FDA as supplemental data carriers on blood products (Hohberger et al. 2011), so experimental tests have to be performed in order to verify the possibility to use also UHF systems in transfusion medicine, and eventually to outline application guidelines.

Tests should verify two fundamental conditions. First, the absence of acute adverse in-vitro effects on blood components following prolonged exposure to UHF radio energy; second, UHF systems reliability in operative conditions.

The research team is currently also improving the economic analysis by taking into account, in addition to the current analysis revenues, benefits that are not immediately cash convertible, anyway attributable as project results. An economic conversion of non-economic benefits analyzed within the Return on Safety assessment, will allow new global financial indicators defining; a new cost-benefits analysis based on these indexes could provide a complete framework for project evaluation.

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NETWORK DATA ENVELOPMENT ANALYSIS OF CONTAINER SHIPPING LINES

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ABSTRACT
In this research a Network Data Envelopment Analysis (DEA) approach is proposed to assess the efficiency of a number of Container Shipping Lines (CSLs). Two stages are considered: one with labour, number of ships and fleet capacity as inputs, and container throughput handled as output and a second stage with the latter as input and turnover as output. A non-oriented Slacks-Based Measure of efficiency (SBM) metric is used. The approach is compared with the conventional single-process DEA. An increase in the discrimination power of the method is obtained by the use of the network DEA approach. In addition, the proposed approach not only computes an overall efficiency score for each CSL but also rates the relative efficiency of its two stages.

Keywords: Container shipping lines, Efficiency, Network DEA, SBM

1. INTRODUCTION

Data Envelopment Analysis (DEA) is a well-known non-parametric technique to assess the relative efficiency of different operating units, commonly referred to as Decision Making Units (DMUs) (Cooper et al. 2006). DEA has been applied in many sectors (education, health care, finance, sports, etc). In particular, there are many applications of DEA in transportation. Thus, DEA has been applied to railways (e.g. Hilmola 2007), airlines (e.g. Lozano and Gutiérrez 2011a), urban transit (e.g. Barros and Peypoch 2009), airports (e.g. Lozano and Gutiérrez 2011b), etc. DEA has also been extensively used to benchmark ports and container terminals (see, e.g., Tongzon 2001, Barros 2003, 2006, Park and De 2004, Lozano 2009, Cullinane and Wang 2010). Also, Managi (2007) applied DEA to estimate the productivity change of Japanese shipping firms. In spite of the importance of container traffic, which has become the fastest growing sector of maritime freight transport, (UNCTAD 2011) there are very few studies on the efficiency of Container Shipping Lines (CSLs). The interest of researchers on this topic is, however, increasing (Lun and Marlow 2011, Panayides et al. 2011).

In this research, DEA is applied to assess the efficiency of CSLs. In particular, a Network DEA approach is proposed. Conventional DEA considers a DMU as a single process assuming that this aggregate process consumes all the different inputs and produces all the different outputs. Network DEA, on the contrary, models the inner structure of the system. Different subprocesses or stages are considered and intermediate products produced and consumed within the system are identified (e.g. Färe and Grosskopf 2000, Färe et al 2007, Kao 2009, Lozano 2011). Network DEA has been applied to different transportation sector problems such as container terminals (Bichou 2011), bus routes (e.g. Sheth et al 2007), multi-mode bus transit (e.g. Yu 2008) railways (e.g. Yu and Lin 2008), airports (e.g. Yu 2010), air routes (e.g. Yu and Chen 2011) and airlines (e.g. Zhu 2011). To the best of our knowledge, no Network DEA approach to CSL operations has been previously proposed.

2. PROPOSED APPROACH

Consider the two-stage network structure shown in Figure 1. The first stage uses labour, number of ships and fleet capacity (in TEUs) as inputs, and container throughput handled as output while the second stage uses the latter as input and turnover as output. The first stage is related to the operative processes while the second is related to the commercial processes. The latter transforms the output of the physical operations (given by the container throughput) into revenue.

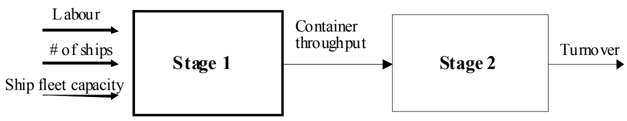

Figure 1: Two-stage network structure

A Slacks-Based Measure of efficiency (SBM) metric is used (Tone and Tsutsui 2009). Let

Stage 1 inputs

L_j Labour of CSL j

NS_j Number of ships of CSL j

FC_j	Fleet capacity of CSL j

Stage 1 output (intermediate product)

CT_j	Container throughput handled by CSL j

Stage 2 output (final product)

T_j	Turnover of CSL j

Variables

$(\lambda_1, \lambda_2, ..., \lambda_N)$	Convex-linear-combination multipliers of Stage 1
$(\mu_1, \mu_2, ..., \mu_N)$	Convex-linear-combination multipliers of Stage 2
s_0^L	Potential reduction of input L for CSL 0
s_0^{NS}	Potential reduction of input NS for CSL 0
s_0^{FC}	Potential reduction of input FC for CSL 0
s_0^T	Potential increase of output T for CSL 0
ξ_0	SBM efficiency of CSL 0

Network DEA model for assessing efficiency of CSL 0

$$\text{Min} \quad \xi_0^{NDEA} = \frac{1 - \frac{1}{3} \cdot \left(\frac{s_0^L}{L_0} + \frac{s_0^{NS}}{NS_0} + \frac{s_0^{FC}}{FC_0} \right)}{1 + \frac{s_0^T}{T_0}} \tag{1}$$

subject to

$$\sum_j \lambda_j L_j = L_0 - s_0^L \tag{2}$$

$$\sum_j \lambda_j NS_j = NS_0 - s_0^{NS} \tag{3}$$

$$\sum_j \lambda_j FC_j = FC_0 - s_0^{FC} \tag{4}$$

$$\sum_j \lambda_j CT_j = \sum_j \mu_j CT_j \geq CT_0 \tag{5}$$

$$\sum_j \mu_j T_j = T_0 + s_0^T \tag{6}$$

$$\sum_j \lambda_j = 1 \tag{7}$$

$$\sum_j \mu_j = 1 \tag{8}$$

All variables non-negative

The above model aims at maximizing the ratio of the output relative increase to the average input relative reduction. Thus, the numerator of the objective function (1) decreases with the increase in the input reductions (a.k.a. input slacks). Since some inputs may experience more reductions than others the average relative reduction is computed. The denominator of (1) is analogous in the sense that it increases as the output slack increase. In this case, since there is only one output, there is no need to use the average value (of the relative output increase).

The efficiency score computed by the proposed approach is directly related to the objective function used and therefore a CSL is assessed efficient if the model cannot find a feasible operation point with equal or less input and equal or less output. On the contrary, if the model is able to find a feasible operation point that consumes equal or less inputs and produces equal or more output than the CSL being assessed then an efficiency score less than unity is given.

The constraints limit the feasible target values for the inputs and outputs to those that lie within the corresponding Variable Returns to Scale (VRS) Production Possibility Set of each process. This is a distinct feature of Network DEA models, i.e. each process/stage has its own set of linear-combination multipliers. Constraints (5) impose, on one hand, the balance between the amounts of the intermediate product produced and consumed, which, on the other hand, should be at least equal to the observed value CT_0.

The above model is non-linear but can be linearised introducing the following variables

$$\begin{aligned} &\tau_0 > 0 \\ &\hat{\lambda}_j = \tau_0 \lambda_j \quad \forall j \\ &\hat{\mu}_j = \tau_0 \mu_j \quad \forall j \\ &\hat{s}_0^X = \tau_0 s_0^X \quad \forall X = L, NS, FC, T \end{aligned} \tag{9}$$

The resulting Linear Programming model is

$$\text{Min} \quad \xi_0^{NDEA} = 1 - \frac{1}{3} \cdot \left(\frac{\hat{s}_0^L}{L_0} + \frac{\hat{s}_0^{NS}}{NS_0} + \frac{\hat{s}_0^{FC}}{FC_0} \right) \tag{10}$$

subject to

$$\tau_0 + \frac{\hat{s}_0^T}{T_0} = 1 \tag{11}$$

$$\sum_j \hat{\lambda}_j L_j = \tau_0 L_0 - \hat{s}_0^L \tag{12}$$

$$\sum_j \hat{\lambda}_j NS_j = \tau_0 NS_0 - \hat{s}_0^{NS} \tag{13}$$

$$\sum_j \hat{\lambda}_j FC_j = \tau_0 FC_0 - \hat{s}_0^{FC} \tag{14}$$

$$\sum_j \hat{\lambda}_j CT_j = \sum_j \hat{\mu}_j CT_j \geq \tau_0 CT_0 \tag{15}$$

$$\sum_j \hat{\mu}_j T_j = \tau_0 T_0 + \hat{s}_0^T \tag{16}$$

$$\sum_j \hat{\lambda}_j = \tau_0 \tag{17}$$

$$\sum_j \hat{\mu}_j = \tau_0 \quad (18)$$

All variables non-negative

The optimal solution of the proposed Network DEA model does not only provide the estimated efficiency score of each DMU but also efficiency scores of each of its two stages as per

$$\xi_0^{Stage1} = 1 - \frac{1}{3} \cdot \left(\frac{s_0^L}{L_0} + \frac{s_0^{NS}}{NS_0} + \frac{s_0^{FC}}{FC_0} \right) \quad (19)$$

$$\xi_0^{Stage2} = \frac{1}{1 + \frac{s_0^T}{T_0}} \quad (20)$$

Moreover, the overall efficiency is the product of the efficiency of the two stages:

$$\xi_0^{NDEA} = \xi_0^{Stage1} \cdot \xi_0^{Stage2} \quad (21)$$

In order to compare the proposed approach with the conventional single-process DEA approach the corresponding linearised model is shown below. Note that a single set of convex-linear-combination multipliers is used. Note also that, in the conventional DEA approach, the CT variable is considered an output and therefore its potential relative increase is also included in the objective function.

Single-Process DEA model for CSL 0

$$\text{Min} \quad \xi_0^{SP} = 1 - \frac{1}{3} \cdot \left(\frac{\hat{s}_0^L}{L_0} + \frac{\hat{s}_0^{NS}}{NS_0} + \frac{\hat{s}_0^{FC}}{FC_0} \right) \quad (22)$$

subject to

$$\tau_0 + \frac{1}{2} \cdot \left(\frac{\hat{s}_0^T}{T_0} + \frac{\hat{s}_0^{CT}}{CT_0} \right) = 1 \quad (23)$$

$$\sum_j \hat{\omega}_j L_j = \tau_0 L_0 - \hat{s}_0^L \quad (24)$$

$$\sum_j \hat{\omega}_j NS_j = \tau_0 NS_0 - \hat{s}_0^{NS} \quad (25)$$

$$\sum_j \hat{\omega}_j FC_j = \tau_0 FC_0 - \hat{s}_0^{FC} \quad (26)$$

$$\sum_j \hat{\omega}_j T_j = \tau_0 T_0 + \hat{s}_0^T \quad (27)$$

$$\sum_j \hat{\omega}_j CT_j = \tau_0 CT_0 + \hat{s}_0^T \quad (28)$$

$$\sum_j \hat{\omega}_j = \tau_0 \quad (29)$$

All variables non-negative

3. RESULTS AND DISCUSSION

In this section, the results of the proposed Network DEA approach are presented and compared with those of the conventional DEA approach. The dataset used involves 15 international major CSLs with a throughput of over 10,000 TEUs and corresponds to year 2009. The research data can be found at Containerisation International (2011). The 2009 annual reports of the selected CSLs were also used. Turnover figures correspond to million US$. Table 1 shows the dataset together with some summary statistics.

Table 1: Dataset used

CSL	L	NS	FC	CT	T
MAERSK	24,500	430	1,753,996	13,800,000	19,962
CMA CGM SA	17,000	284	944,514	7,882,000	10,600
HAPAG LLOYD	6,670	112	460,241	4,637,000	6,194
COSCON	71,584	142	490,836	5,200,000	4,307
EVERGREEN LINE	4,141	167	593,443	5,815,000	2,704
APL	19,500	129	528,515	4,930,000	5,485
CSCL	4,311	121	457,648	6,700,000	3,090
OOCL	7,748	64	297,367	4,159,000	4,350
CSAV	6,972	65	194,010	1,790,500	3,028
HAMBURG SUD	4,791	90	288,297	2,300,000	4,463
KLINE	7,119	92	334,741	3,081,000	10,983
YML	4,197	82	325,828	2,780,000	2,934
HMM	2,038	52	255,643	2,510,000	5,256
WAN HAI	769	63	122,069	2,685,166	1,595
DELMAS	727	63	90,978	692,000	1,766
Mean	12,138	130.4	475,975	4,597,444	5,781
Standard dev.	17,867	101.6	412,429	3,207,943	4,810
Minimum	727	52	90,978	692,000	1,595
Maximum	71,584	430	1,753,996	13,800,000	19,962
Sum	182,067	1,956	7,138,126	68,961,666	86,718

Table 2 shows the efficiency scores computed by conventional DEA and Network DEA. For the latter, the efficiency scores of the two stages are also shown. Note that Single-Process DEA has less discriminant power overestimating efficiency and assessing almost half of the CSLs as relative efficient. On the contrary, Network DEA is more demanding: a DMU is efficient if and only if all its stages are efficient. That only happens in the case of two CSLs, namely MAERSK and DELMAS. However, it is not by chance that these two CSLs are the largest and the smallest DMUs in the sample. It is common, when VRS are assumed, that this happens. Note also that there are some CSLs with an efficiency score of unity for one of the two stages. In general, the efficiency of the stage 1 is higher than that of the second stage.

Table 2: Efficiency scores

CSL	ξ_0^{SP}	ξ_0^{NDEA}	ξ_0^{Stage1}	ξ_0^{Stage2}
MAERSK	1.000	1.000	1.000	1.000
CMA CGM SA	0.761	0.417	0.591	0.706
HAPAG LLOYD	0.797	0.304	0.602	0.504
COSCON	0.521	0.160	0.473	0.338
EVERGREEN LINE	0.639	0.146	0.716	0.204
APL	0.550	0.214	0.489	0.438
CSCL	1.000	0.221	1.000	0.221
OOCL	1.000	0.366	1.000	0.366
CSAV	0.530	0.182	0.570	0.320
HAMBURG SUD	0.555	0.202	0.428	0.472
KLINE	1.000	0.456	0.456	1.000
YML	0.494	0.138	0.462	0.299
HMM	1.000	0.599	1.000	0.599
WAN HAI	1.000	0.169	1.000	0.169
DELMAS	1.000	1.000	1.000	1.000

Figure 2 shows the cumulative frequency of the efficiency scores of the CSLs computed by the two methods. It can be readily noted that the relative efficiency scores computed by Single-Process DEA are more generous than those estimated by Network DEA. Our claim is that the latter are more valid since they have been computed using a more fine-grained approach that instead of considering a DMU as a black box distinguishes different stages.

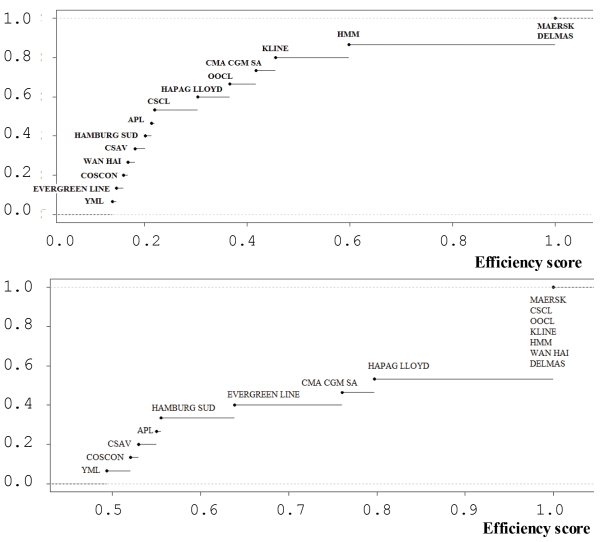

Figure 2: Cumulative distribution of efficiency scores

Table 3 shows, for the proposed Network DEA approach, the slacks (i.e. potential improvements) of the different variables as well as the sum of all of them in absolute and in relative terms. Table 4 shows the corresponding values for the Single-Process DEA. It can be noted that Network DEA is able to find more inefficiencies than conventional DEA, especially in the Turnover variable.

Table 3: Potential improvements (Network DEA)

CSL	L	NS	FC	CT	T
MAERSK	0	0	0	0	0
CMA CGM SA	9,328	112	271,052	0	4,404
HAPAG LLOYD	4,179	21	175,028	0	6,092
COSCON	68,596	43	158,565	0	8,451
EVERGREEN LINE	611	59	209,768	0	10,569
APL	16,751	34	218,812	0	7,047
CSCL	0	0	0	0	10,924
OOCL	0	0	0	0	7,536
CSAV	6,203	2	71,941	894,666	6,428
HAMBURG SUD	4,022	27	166,228	385,166	4,992
KLINE	6,001	23	179,586	0	0
YML	3,344	18	195,832	0	6,888
HMM	0	0	0	0	3,524
WAN HAI	0	0	0	0	7,861
DELMAS	0	0	0	0	0
Total	119,035	337	1,646,812	1,279,834	84,716
	65.4%	17.2%	23.1%	1.9%	97.7%

Table 4: Potential improvements (Single-Process DEA)

CSL	L	NS	FC	CT	T
MAERSK	0	0	0	0	0
CMA CGM SA	5,594	75	117,726	0	0
HAPAG LLOYD	758	8	72,656	0	1,395
COSCON	7,712	13	0	0	4,635
EVERGREEN LINE	0	59	175,110	0	1,235
APL	13,816	22	130,979	0	1,466
CSCL	0	0	0	0	0
OOCL	0	0	0	0	0
CSAV	5,520	8	0	800,324	539
HAMBURG SUD	2,753	38	32,654	210,000	793
KLINE	0	0	0	0	0
YML	2,013	26	57,168	0	2,183
HMM	0	0	0	0	0
WAN HAI	0	0	0	0	0
DELMAS	0	0	0	0	0
Total	38,165	248	586,293	1,010,324	12,244
	30.4%	12.7%	8.2%	1.5%	14.1%

4. CONCLUSIONS AND FURTHER RESEARCH

In this paper the relative efficiency of major international CSLs has been analyzed. To that end, a new Network DEA approach has been used, which is able to carry out a finer performance assessment. The proposed approach distinguishes two stages which correspond to the operations and commercial subsystems, respectively. It has been found that almost all CSLs are inefficient in one or another (or both) stages. Only two (MAERSK and DELMAS) are overall efficient. Significant capacity slacks have been found in the payroll and fleet size (both in terms of number of ships and TEU capacity). Although in some cases an increase in container throughput has also been estimated, the largest inefficiency lies in the commercial subsystem where, extending the best practices to all CSLs, a substantial (of almost 100% in average) increase in turnover would be attainable.

A limitation of this study is that it draws a static analysis of the situation, and precisely in a rather special year, in the midst of the current economic crisis. Extending the study to a longer period would allow a more complete analysis, including productivity changes. Enlarging the dataset would also help to better gauge efficiency although, as it happens often, the size of the dataset is severely restricted by data availability issues. Also, should data on additional variables (e.g. operating costs, work accidents, etc) be available a more detailed DEA model could be used.

Finally, although our claim is that the efficiency scores computed by Network DEA are more valid than those obtained by the conventional single-process DEA, such superiority cannot be proved neither on theoretical nor on empirical grounds. The claim is based on two ideas. One is that Network DEA uses more information and therefore its analysis is more fine-grained. The second idea is that Network DEA has more discriminant power than single-process DEA. Further research on this topic is warranted.

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COMPARATIVE STUDY OF MULTIPLE CRITERIA METHODS FOR CHOOSING CARGO TRANSPORTATION MODE

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ABSTRACT
The paper considers the evaluation of the efficiency of multiple criteria methods employing for the choice of freight transportation mode and route. The following main tasks are highlighted: selection of a set of indices, characterizing efficiency of freight transportations, and formation of efficiency criteria of the transportation system on their basis; choice of multiple criteria methods for evaluation and selection of cargo transportation alternatives; evaluation and selection of cargo transportation routes and modes using AHP and ELECTRE methods; comparison of the results of choice obtained by different methods; evaluation of the efficiency of AHP and ELECTRE methods employed to solve the problem of choosing the freight transportation route and mode.

Keywords: cargo transportation, route, choice criteria, multiple criteria decision analysis

1. INTRODUCTION

Search for the best solution or finding a set of good alternatives in realization of freight transportation should be based on the different initial data, considering logistic principles, and be done using modern mathematical methods and information technologies (Ghiani, Laporte and Musmanno 2004; Lukinsky 2008). Solving the choice problem we have to take into account such important factors as: a complicated structure of transportation, high dynamics and rapidity of transport processes, the random factors influencing these processes, and geographical dispersion of participants of the transportation.

In case of freight transportation by one transport the task of finding the optimal route is solved as the shortest path problem by employing the methods of mathematical programming (for example, see Cherkassky, Goldberg and Radzik 1996; Ravindra et al. 1993). As a rule, the task is solved in the single-criterion setting, and this criterion is the shortest path of cargo transportation. Along with this the transportation companies are interested in optimization of different indicators in the process of the route choosing: delivery time, cost of transportation, number of transport facilities, etc. Even under the condition of employing several criteria the task of searching for the optimal route is quite often reduced to the single-criterion setting, moreover, all the criteria are comprised in the integral one (most commonly, it is a cost criterion), by sometimes summing up all of them with their own weights, or by choosing one optimization criterion from the group of criteria and the remaining criteria are used as constraints. Many researchers are interested in multi-criteria shortest path problems and suggest different approaches to it, they are as follows: bicriteria path problems (Hansen 1979; Henig 1985), multi-criteria shortest path problem (Martins 984), multi-criteria Pareto Search (Muller-Hannemann and Schnee 2004).

Considering the multimodal freight transportation, the task of choosing the optimal solution becomes significantly complicated, since it comprises not only the choice of route, but also mode of transportation, the freight transhipment and warehousing on route. As a rule, it is considered as the task of multiple criteria choice. This approach does not require the employment of complicated apparatus of mathematical programming and suggests numerous methods based on the expert evaluation.

There are a number of researches for expert evaluating and choosing the alternatives of cargo transportation, for example, see analysis in (Gursoy 2010). Similar to classical optimization approach, there are two variants of creating the choosing criteria: reducing all the criteria to the integrated criterion (for example, see Ivanova, Toikka and Hilmola 2006), and employing the independent choice criteria. Multiple criteria approach is implemented in the work (Gursoy 2010), where three criteria for route choice (shipping time, shipping price, shipping safety) are applied. But in practice there exist more different criteria which determine the efficiency of cargo transportation (Kopytov and Abramov 2011).

In the presented research, the following main tasks, which require solutions, are highlighted:

- Selection of a set of indices, characterizing efficiency of multimodal freight transportations, and formation of efficiency criteria of the transportation system on their basis;
- Choice of multiple criteria methods for evaluation and selection of cargo transportation alternatives;
- Evaluation and selection of cargo transportation routes and modes using suggested methods;
- Comparison the results of choice, obtained by different methods; evaluation of the efficiency of suggested methods employed to solve the problem of choosing the best route and mode of multimodal freight transportation.

2. CRITERIA OF EFFICIENCY OF FREIGHT TRANSPORTATIONS

To estimate the efficiency of transportation, the system of criteria including cost, duration, reliability and ecological safety of cargo transportation is used.

Delivery costs includes financial costs for performing transportation of goods from origin to destination points, including costs for loading, transportation and handling, costs connected to the customs clearance, documentation, storage, demurrage and others.

Delivery time is a total time needed to move goods from origin point to destination point, including time for loading, transportation and handling, time for border crossing and customs clearance.

Reliability of the transportation system is a complex criterion, which includes indices like reliability of transportation (fulfillment of delivery time, reliability of transport means, fulfillment of other transportation contract terms and others) and safety of transportation (safety of cargo, protection from unauthorized access to cargo and others).

Ecological impact is criterion, which reflects losses from the harmful impacts of transportation means on the environment on the different routes, as well as cost of activities for protection of the environment from these harmful impacts. Another important issue is safety of activity of the people (emissions of harmful substances in the atmosphere, the soil and reservoirs, death and a traumatism of people, destruction of buildings and constructions as a consequence of their vibration, etc.).

It is easy to notice that the suggested indices have the various physical natures and are measured by different physical magnitudes. The part of indices is deterministic, the part is stochastic. Additional difficulties for estimating the system indices are related to the fact that part of indices has quantitative nature and part has qualitative nature. For example, cost and durations of transportation are quantities, but reliability, safety and environmental impact, estimated by experts, are qualitative parameters.

3. METHODS OF ESTIMATION OF THE SELECTED CRITERIA

There are currently various methods that have been developed and implemented to analyze and choose from a range of alternatives using different criteria. These methods include multiple criteria decision making (MCDM), multiple criteria decision analysis (MCDA), and multiple attribute decision making (MADM) (Köksalan, Wallenius and Zionts 2011). The existence of this variety of methods makes the issue of choosing the most suitable one rather difficult (Triantaphyllou 2000).

In the authors' opinion the MCDA methods of pairwise comparison are the most suitable for the examined problem. In the given paper the authors have analysed the possibility of employing for the choosing cargo transportation route and mode the most popular pairwise comparison methods: Analytic Hierarchy Process (AHP) method (Saaty 2001) and ELECTRE methods (Figueira, Mousseau and Roy 2005).

4. EVALUATION AND SELECTION OF CARGO TRANSPORTATION ROUTES

To illustrate the suggested AHP and ELECTRE methods efficiency for choosing the freight transportation route and mode, five alternative routes from Shanghai to Moscow have been evaluated. The suggested routes are as follows: Shanghai – Hamburg – Riga – Tver – Moscow; Shanghai – Vladivostok – Rail Terminal in Moscow – Warehouse in Moscow; Shanghai – Hamburg – Kotka – Tver – Moscow; Shanghai – Hamburg – Klaipeda – Tver – Moscow; Shanghai – Alashankou – Dostyk – Rail Terminal in Moscow – Warehouse in Moscow.

Let us consider each route and its transportation mode in details.

Route A: Shanghai – Hamburg – Riga – Tver – Moscow. This route considers transportation of cargo from Shanghai to Hamburg by mother vessel. Thereafter container is being reloaded onto feeder vessel for delivery to the port of Riga. In Riga container is reloaded onto truck and delivered to the customs terminal in Tver. After customs clearance container is delivered to warehouse in Moscow for unloading.

Route B: Shanghai – Vladivostok – Railway terminal in Moscow – Warehouse in Moscow. Cargo in container is delivered from Shanghai to Vladivostok by vessel, where customs clearance is being done. Further the container is loaded onto rail platform and delivered to rail terminal in Moscow. At the terminal the container is being reloaded on truck and delivered to the warehouse of consignee.

Route C: Shanghai – Hamburg – Kotka – Tver – Moscow. This route considers transportation of cargo from Shanghai to Hamburg by mother vessel. Thereafter container is being reloaded onto feeder vessel for delivery to the port of Kotka. In Kotka container is reloaded onto truck and delivered to the customs terminal in Tver. After customs clearance container is delivered to warehouse in Moscow for unloading.

Route D: Shanghai – Hamburg – Klaipeda – Tver – Moscow. This route considers transportation of cargo from Shanghai to Hamburg by mother vessel. Thereafter container is being reloaded onto feeder vessel for delivery to the port of Klaipeda. In Klaipeda container is reloaded onto truck and delivered to the customs terminal in Tver. After customs clearance container is delivered to warehouse in Moscow for unloading.

Route E: Shanghai – Alashankou – Dosty – Rail Terminal in Moscow – Warehouse in Moscow. Cargo in container is delivered from Shanghai to Alashankou by short see vessel. In Alashankou container is reloaded onto railway platform and further delivered to Dostyk, Chinese/Kazakhstan border point. In Dostyk the container is reloaded onto railway platform of Kazakhstan railways (changing the gauge). Further the container is being delivered to rail terminal in Moscow, where customs clearance is done. After customs clearance the container is reloaded on truck and delivered to the warehouse of consignee.

Results of calculations of two basic indices of efficiency (average transportation cost and delivery time) of the chosen routes of freight transportation are presented in Table 1 (see Kopytov and Abramov 2012).

Table 1: Efficiency indices of logistic systems

Route	Transportation cost, USD	Delivery time, days
A	6300	40
B	7500	25
C	6600	40
D	6800	42
E	9000	40

As it is evident from the table the decision-maker can not get a clear answer on the question what route to choose. On the one hand, the route A has the lowest cost of cargo transportation, but its delivery time is 15 days greater than the smallest time. On the other hand, the route B, which has the smallest delivery time, is more expensive (the cost is 19% greater). For the choice of route the priority between cost and delivery time should be chosen or multiple criteria decision method should be applied. Implementation of multiple criteria approach allows taking into consideration other criteria in the process of choosing the mode and route of the freight transportation; in considered case they are safety and ecological compatibility of transportation.

5. CHOICE OF TRANSPORTATION ROUTE AND MODE USING AHP METHOD

Complete calculation by 22 criteria, offered by the authors and united into such groups as cost, duration, reliability and ecological safety of transportation of cargo, is considered in (Kopytov and Abramov 2012). In present article we consider only the calculation of four criteria of the first hierarchy level for each group.

To perform the calculations of criteria, the authors have used standard algorithms of the AHP method with the commonly used pairwise comparison scale 1-9. This scale proposed by Saaty (2001) has the following values:

1 – if alternatives A and B are equal in importance;
3 – if A is slightly more important than B;
5 – if A is significantly more important than B;
7 – if A is very significantly more important than B;
9 – if A is absolutely more important than B;

and 2, 4, 6, and 8 are intermediate values between the two adjacent judgments.

The summary data of the experts' pairwise comparisons for criteria of cargo transportation are presented in Table 2. The importance of the criteria is evident from the evaluation of the criteria priority vector. It is easy to notice that criterion "Cost" with value 0,5813 of priority vector is more important for the multimodal freight transportation.

Table 2: Paired comparisons matrix for criteria

Criteria	Cost	Time	Reliability	Ecological impact	Priority vector
Cost	1	4	5	6	0,581288
Time	1/4	1	2	5	0,220842
Reliability	1/5	1/2	1	5	0,147686
Ecological impact	1/6	1/5	1/5	1	0,050185

The evaluations of the vector of the global alternatives priorities are shown above in Table 3. The results of the evaluations show that route B has the highest value of priority 0,291997 and will be selected for cargo transportation from Shanghai to Moscow.

Table 3: Evaluating result for freight transportation from Shanghai to Moscow

Alternatives	Criteria				Global priorities
	Cost	Time	Reliability	Ecological impact	
	Numerical value of priority vector				
	0,581288	0,220842	0,147686	0,050185	
Route A	0,290658	0,079618	0,125299	0,063250	0,208218
Route B	0,194134	0,487666	0,371898	0,329346	0,291997
Route C	0,226390	0,121666	0,108371	0,074537	0,178212
Route D	0,223518	0,068267	0,135682	0,067550	0,168433
Route E	0,065299	0,242783	0,258749	0,465317	0,153140

6. CHOICE OF TRANSPORTATION ROUTE AND MODE USING ELECTRE METHOD

The authors have chosen ELECTRE 1, the first outranking method of the ELECTRE methods family (Figueira, Mousseau and Roy 2005; Bouyssou et al. 2006), for applying in considered research. The algorithm of sorting and choosing the best alternatives of freight transportation for the specified criteria includes the following steps:

1) determining the weights of criteria;
2) determining the scales for criteria;

3) estimation of the alternatives according to all criteria;

4) calculation of the concordance and discordance set and determining the concordance dominance matrix;

5) determining the dominating and the dominated alternatives for suggested levels of the concordance and discordance and generating the new core of alternatives by eliminating the dominated alternatives from the existing set of alternatives;

6) if, in analyst's opinion, the number of alternatives within the core is high, specifying the "weaker" values of concordance and discordance levels (the lower value of concordance level and higher value of discordance level) and repeating the process from point 5, otherwise finishing the actions.

It is necessary to note that the last core comprises the best alternatives. The cores succession determines the sorting of alternatives by quality. The results of implementing the specified steps of algorithm are presented below in Table 4 – Tables 9.

Step 1. The criteria weights are shown in Table 4. The importance of β_i criterion is estimated by 10-grades scale (see line 2 of the table), and the criteria weights W_i are calculated by formula:

$$W_i = \frac{\beta_i}{\sum_{i=1}^{4} \beta_i}; \quad i = 1, 2, ..., 4. \tag{1}$$

Table 4: Weights of criteria

	Cost	Time	Reliability	Ecological impact
i	1	2	3	4
β_i	8	5	3	1
W_i	0,471	0,294	0,176	0,059

Step 2. There introduced the scales for measuring the indicators: 25-grade scale for transportation cost and time, and 4-grade scale for other indicators (see Table 5).

Step 3. Every route is estimated by implementing the calculation results from Table 1 and assessment given by experts for two last indicators; they result in Table 6. It is evident that route D is dominated by route A and not included in Pareto set of solutions. Using the ELECTRE method, the route D is left at the initial set of alternatives, such approach corresponds to the existing practice.

Pairwise comparisons of routes by every criterion are presented in Table 7. For the pair of routes A-B we denote by "+" the case when A is strictly preferred to B; by "=" the case when A is indifferent (equals) to B, and by "–" the case when B is strictly preferred to A.

Step 4. The set of criteria $\mathbf{I} = \{1, 2, 3, 4\}$ is divided into three subset for every pair of alternatives A and B: subset $\mathbf{I}^+$ in which A is more preferable than B; subset $\mathbf{I}^-$ in which B is more preferable than A; and subset $\mathbf{I}^=$ in which A is indifferent to B.

Table 5: Criteria scales

Criterion	Value	Scale value
Cost	6000 - 6800 USD	25
	6900 - 7800 USD	20
	7900 - 8800 USD	15
	8900 - 9800 USD	10
Time	25 - 30 days	25
	30 - 35 days	20
	35 - 40 days	15
	40 - 45 days	10
Reliability	Bad	1
	Satisfactory	2
	Good	3
	Very Good	4
Ecological impact	Bad	1
	Satisfactory	2
	Good	3
	Very Good	4

Table 6: Assessment of the routes

Route	Cost	Time	Reliability	Ecological impact
A	25	10	2	2
B	15	25	3	3
C	20	15	2	2
D	20	10	2	2
E	10	20	3	4

Employing sets $\mathbf{I}^+$, $\mathbf{I}^-$ and $\mathbf{I}^=$ the concordance indices C_{AB} and disconcordance indexes D_{AB} are calculated for every pair of alternatives A and B using the following formulae:

$$C_{\text{AB}} = \frac{\sum_{i \in \mathbf{I}^+} W_i + 0,5 \sum_{i \in \mathbf{I}^=} W_i}{\sum_{i=1}^{4} W_i}; \tag{2}$$

$$D_{\text{AB}} = \max_{i \in \mathbf{I}^-} \frac{l_{\text{B}}^{(i)} - l_{\text{A}}^{(i)}}{L_i}, \tag{3}$$

where $l_{\text{B}}^{(i)}$ and $l_{\text{A}}^{(i)}$ are values of i-th criterion for A и B respectively; L_i is maximum value of i-th criterion scale.

The results of concordance and discordance matrices calculations are presented in Tables 8 and 9.

Step 5. The binary preference of A alternative over B alternative for specified levels of concordance p and discordance q is checked for conditions implementation:

$$C_{\text{AB}} \geq p \text{ и } D_{\text{AB}} \leq q. \tag{4}$$

Route B is dominated and it can be excluded from the considered set by generating the new core of alternatives.

Table 7: Pairwise comparisons of routes

Pair of routes	Cost	Time	Reliability	Ecological impact
A-B	+	–	–	–
B-A	–	+	+	+
A-C	+	–	=	=
C-A	–	+	=	=
A-D	+	=	=	=
D-A	–	=	=	=
A-E	+	–	–	–
E-A	–	+	+	+
B-C	–	+	+	+
C-B	+	–	–	–
B-D	–	+	+	+
D-B	+	–	–	–
B-E	+	+	=	–
E-B	–	–	=	+
C-D	=	+	=	=
D-C	=	–	=	=
C-E	+	–	–	–
E-C	–	+	+	+
D-E	+	–	–	–
E-D	–	+	+	+

Table 8: Concordance matrix

Route	A	B	C	D	E
A	-	0,47	0,59	0,74	0,47
B	0,53	-	0,53	0,53	0,85
C	0,41	0,47	-	0,65	0,47
D	0,26	0,47	0,35	-	0,47
E	0,53	0,15	0,53	0,53	-

Table 9: Discordance matrix

Route	A	B	C	D	E
A	-	0,6	0,2	0	0,5
B	0,4	-	0,2	0,2	0,25
C	0,2	0,4	-	0	0,5
D	0,2	0,6	0,2	-	0,5
E	0,6	0,2	0,4	0,4	-

The first step specifies p=0,74 and q=0,25. As Tables 8 and 9 show, the condition (4) is performed for pair A-D and B-E. Then routes D and E are dominated and they can be excluded from the considered set of alternatives. Consequently, the core of considered alternatives now comprises three routes: A, B and C (shown by dotted line in Fig.1)

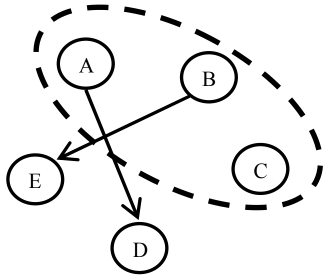

Figure 1: Core of alternatives A, B and C

Step 6. The level of concordance p is decreased by p=0,59, while the discordance is still q=0,25. The condition (4) is performed for pair A-C, and the route C is dominated and for p and q levels the new core of the best alternatives comprises two routes A and B (Fig. 2).

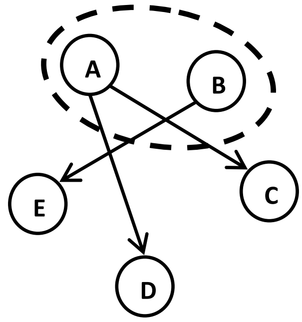

Figure 2: Core of alternatives A и B

7. EVALUATION OF THE EFFICIENCY OF SUGGESTED METHODS EMPLOYING

There is a consideration of the results of choosing the route and mode of freight transportation received by employing the methods AHP and ELECTRE (see Sections 5 and 6). The results of evaluation of freight transportation routes from Shanghai to Moscow, received by using methods AHP and ELECTRE, allow defining the most favourable routes and transportation modes. In general the obtained results are very similar to each other. So, choosing the alternative by AHP method, the route B is determined to be the best one, and the route A is the second in preference (see Table 3 above). Under implementing the ELECTRE method, the routes A and B are the best ones.

For *evaluation methods AHP and ELECTRE* the authors have formed the system of criteria including eleven indicators. These indicators were distributed in two groups: estimated by developers (programmers) and estimated by users (analytics) accordingly.

Group #1 "Users" estimated by users (analytics) includes eight indicators:

- simplicity of usage;
- visualization of results;
- control of estimates consistency;

- uncertainties in the analysis and calculations;
- flexibility of the analysis process;
- possibility of obtaining quantitative estimates for each alternative;
- possibility of separating assessment procedure for different experts;
- possibility of preferred alternatives changing.

Group #2 "Developers" estimated by developers includes three indicators:

- simplicity of realization;
- simplicity of modification (when the set of criteria or/and the set of alternatives are changed);
- dependence of the realization complexity on number of criteria and alternatives.

To evaluate each indicator the authors have selected the numeric scale from 1 to 10, where 1 means unsatisfactory; 10 – excellent. The effectiveness of choice methods for the selected groups of criteria is characterized by the following criteria:

1) *the sum of scores* $S_j^{(i)}$, where $j=1$ for AHP method and $j=2$ for ELECTRE 1 method, where numbers of groups of criteria are $i=1,2$;
2) *the priority vector* (local criteria) $p_i=[p_{i,1},p_{i,2}]$, where the elements of the vector, respectively, define priorities (weights) of the methods AHP and ELECTRE 1 calculated for the *i*-th group of criteria as follows:

$$p_{i,j}=\frac{S_j^{(i)}}{S_1^{(i)}+S_2^{(i)}},\quad j=1,2. \tag{5}$$

It is easy to see that it is always $p_{i,1}+p_{i,2}=1$.

In the final step of the assessment process the vector $P=[P_1,P_2]$ of the *global criteria priorities* can be calculated:

$$P_j=\sum_{i=1}^{2}\beta_i p_{i,j},\quad j=1,2, \tag{6}$$

where $\beta_i, i=1,2$ are the weights of relative importance of the local (group); $\beta_i>0, i=1,2;\ \ \beta_1+\beta_2=1$.

In considered research the weights of local criteria suggested by experts are: $\beta_1=0,65$ and $\beta_2=0,35$.

A numerical weight or priority has been derived for each group of criteria (see Tables 10 – 11). Each group of criteria has been evaluated by four experts, and then average value of each indicator has been calculated. In both groups the criteria values of AHP method are greater (from 0,14 till 0,18) than the criteria values of ELECTRE, but each method has its own advantages.

Using formulas (5), (6) and the results of criteria assessment presented in Tables 10 and 11, we can calculate the global criteria priorities: p_1=0,58 for AHP method and p_2=0,42 for ELECTRE method. So, the global criteria for AHP method is greater than the global criteria for ELECTRE 1 method by 0,16.

Table 10: Assessment of AHP and ELECTRE 1 methods for criteria group "Users"

Indicator	Method	
	AHP	ELECTRE
Simplicity of usage	3	5
Visualization of results	6	6
Control of consistency	8	2
Uncertainties	5	4
Quantitative estimates	8	2
Flexibility of the analysis	4	8
Separating assessment	8	4
Preferred alternatives changing	8	4
Sum of score	50	35
Criteria priorities	0,59	0,41

Table 11: Assessment of AHP and ELECTRE 1 methods for criteria group "Developers"

Indicator	Method	
	AHP	ELECTRE
Simplicity of realization	6	4
Simplicity of modification	4	6
Dependence of the realization complexity	6	2
Sum of score	16	12
Criteria priorities	0,57	0,43

The AHP seems to be the most attractive choice in this context since it allows structuring the choice procedure as a hierarchy of several levels. It allows distribution of criteria into several groups; consequently, the different groups of criteria can be evaluated by different experts. For instance, the economists have assessed the cost criteria; the transport technologists have evaluated the reliability and ecological criteria, while the managers have estimated the time criteria. The opportunity of the pairwise comparison of a smaller number of criteria in every group allows experts to determine better weighted values according to these criteria. The AHP method also allows the possibility of controlling the consistency of the experts' judgements, making it possible to increase the reliability of estimation. In summary, the multi-criteria analysis determined the AHP as the most suitable method for comparative evaluation of different alternatives of the cargo transportation.

When implementing the ELECTRE 1 method, the authors faced the problem of arranging the alternatives in the criteria table (assigning the weights). The use of a large number of criteria (Kopytov, E., Abramov, D., 2012) belonging to different professional knowledge areas resulted in an inadequate estimation of each criterion significance. With the help of invited experts, the authors were only able to competently evaluate certain criteria which they know well. The estimations of other criteria have been executed at by guess-work. Since the assigned weights of criteria have a great impact on the alternative choice, the authors have come to the conclusion that this method would result in largely inaccurate results.

But ELECTRE methods have some advantages too. The main advantages of ELECTRE 1 method are flexibility of the analysis process and possibility of preferred alternatives changing. The important merit of ELECTRE methods is staging of preferences detection for the decision maker taking the procedure of specifying the levels of concordance and discordance and cores examination. The analyst offers the whole range of possible solutions of the problem in the form of different cores to the decision maker. The concept of incomparableness employed in ELECTRE methods, is exceptionally significant from the practical point of view. It allows detecting the routes with "contrast" estimates for special examination.

CONCLUSIONS

The presented study has demonstrated that the AHP and ELECTRE methods can be used to solve the problem of choosing the best cargo transportation route and mode. In general the results obtained by AHP and ELECTRE methods are similar to each other.

In the judgment of the authors, AHP method is the most efficient for choosing the optimal logistic system. The method allows arranging the alternatives of trasportation in the order of their efficiency and showing their difference in the given set of criteria.

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BASIC ARCHITECTURE OF THE „SEMANTICALLY ENRICHED E-WORKING PLATFORM“

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ABSTRACT
The term crowdsourcing denotes the outsourcing of tasks for division of labour to a large number of individuals who offer their skills, capacities and intelligence via the internet. Currently these are mostly intrinsically motivated amateurs, who often complete diverse jobs with no or low remuneration. The main intention of the project Semantically Enriched E-Working Platform (SEEWOP) is to make crowdsourcing to an attractive offer for enterprises as e-working method for special fields of activity in addition to conventional working methods. For this purpose Web 2.0 will be combined with Semantic Web technologies, enabling the annotation of tasks and their specifications, e-workers and their qualifications as well as results and their quality in machine processable form. Therefore, adequate vocabularies and ontologies have to be designed to enable automatic and intelligent division of tasks within the e-worker community. Additionally, a semantic description of processes and rules for routine jobs will be developed.

Keywords: e-work, crowdsourcing, semantic web

1. INTRODUCTION

In June 2006, Jeff Howe as one of the first authors used the term crowdsourcing in the Wired Magazine (Jeff Howe 2006) and argued that the concept of crowdsourcing mainly depends on the fact that it is an open call to an undefined group of persons, and those win, who run tasks best, solve complex problems and contribute the most relevant and freshest ideas. For example, the public will be invited to develop a new technology, to implement a new design (community-based design, design by democracy), to refine or perform an algorithm (human-based computation), or to help to collect large amounts of data, to systematize or analyse (citizen science). Therefore, crowdsourcing has become synonymous for the cooperation of the masses enabled by Web 2.0.

Viewed from the perspective of the research field of e-mobility, these platforms provide an interesting potential that can bring benefits to so-called e-workers as well as to businesses by transition to flexible employer-employee relationships. E-Mobility in this context is not understood in terms of electrical mobility using electric or hybrid vehicles, and even not primarily in terms of wireless communication with mobile devices such as smart phones – although these may of course play a role in the technical implementation –, but refers to the execution of tasks and business processes via the internet, both, to minimize the need for physical mobility to increase energy efficiency in times of rising energy costs, and on the other hand, to allow greater flexibility of individuals with regard to time and place of work performance and an improved accordance of work with leisure and family.

The European Commission already determined in 1998 that in future a hybrid form of work will establish itself, in which physical work and telecommuting – employees do at least some of the work outside the premises of the employer – are indistinguishable (Bundeskanzleramt Österreich 2010).

As part of our research, we deal with e-mobility in the context defined above. To answer the research question, *"What can be done to implement e-mobility for all involved parties (e-managers, e-workers and their environment) successfully?"*, an integrated software solution will be designed that allows both, companies (requesters) and individuals (employees, contractors), to cope with the new challenges encountered in planning, coordination and communication in business as well as in the private environment. The management of e-work shall be enabled by an intelligent crowdsourcing platform – the *Semantically Enriched E-Working Platform (SEEWOP)* – which supports the management of complex tasks by semantic technologies.

2. STATE OF THE ART

For over a decade, on the one hand crowdsourcing established itself as one of the key Web 2.0 applications in many different areas. On the other hand the World Wide Web Consortium (W3C) promotes the development of the Semantic Web, to improve interoperability between different Internet data sources by means of controlled vocabularies, and to allow automated processing of tasks that were previously subjected to human users only. These two components form the basis for the SEEWOP system architecture and are therefore described in this section.

2.1. Crowdsourcing Platforms

The world's largest collection of knowledge on the Internet *Wikipedia* (*http://www.wikipedia.org/*) is one of the first crowdsourcing platforms emerged. Since 2001 thousands of people gather daily information and make their contributions freely available to the public (Miscellaneous Authors 2012).

Another typical example follows a completely different intention. The web-based job-marketplace *Amazon Mechanical Turk* (*http://www.mturk.com*) exists since November 2005 and allows requestors (companies) to find those people who are able to perform tasks that cannot or just poorly be solved by software (e.g.: transcription of audio or video files, data verification or cleanup, generation of large test data sets, sentiment analysis, translation, etc.). These tasks are called *Human Intelligent Tasks (HITs)* and are divided into very small sections. Their processing requires very little time, so usually compensation is only a few dollar cents per HIT (Amazon Mechanical Turk 2012).

However, there are other platforms that use crowdsourcing for the provision of more complex, collaborative creative services, usually in the form of competitions, from concept development to the design of technical equipment. Thus since 2000, on the website *Threadless* (*http://www.threadless.com/*), hundreds of users daily face up voluntarily and without charge to a weekly design competition to let their own T-shirt design ideas be assessed by a community. Winning designs that are actually produced may expect a cash prize by the company. However, the real winner is the company itself that only brings products to market, which enjoyed a great response in advance. Thus, according to the Forbes business magazine, in 2009 the company was able to generate a sales volume of 30 million $ by 50 employees. The about 1.8 million members of this internet community have two important functions: they act both as an outsourced design department, continuously developing new designs virtually free of charge and secondly, they are the customers who enthusiastically buy those T-shirts (Burkitt 2010).

Meanwhile, also crowdsourcing platforms for scientific issues and for the development of innovative solutions are emerging. This group, for example, includes the portal InnoCentive (http://www.innocentive.com/), a mediation platform for scientific services existing since 2001. Under the self-chosen slogan "Challenge-Driven Innovation" the platform primarily addresses scientists and technicians (so-called problem solvers) to apply with their innovative solutions to problems described by companies in the context of challenges. Selected solutions are rewarded with a previously announced amount. According to information of the operating company currently more than 250,000 solvers from 200 countries are available (InnoCentive 2012).

These four examples show the wide range of activities that are now covered by crowdsourcing. They illustrate but also accept that the great advantage of such platforms is currently closer to the requesters who, compared to conventional employment relationships, can generate a multiple of content, ideas and solutions at low costs, while e-workers usually can expect only a very small reward for their efforts.

2.2. Semantic Web

Sir Tim Berners-Lee applies with his definition "The Semantic Web is an extension of the current web in which information is given well-defined meaning, better enabling computers and people to work in cooperation." (Berners-Lee et al. 2001) as founder of the Semantic Web. His vision is that electronic content (the Web) can be read and processed not only by humans but by machines. The World Wide Web Consortium (W3C) defines the Semantic Web as follows: "The Semantic Web is a 'web of data' that enables machines to understand the semantics, or meaning, of information on the World Wide Web" (World Wide Web Consortium 2012) and defines with the so called Semantic Web Stack (see Figure 1) a collection of technologies to store data, to build vocabularies, and to describe rules for querying and automated reasoning.

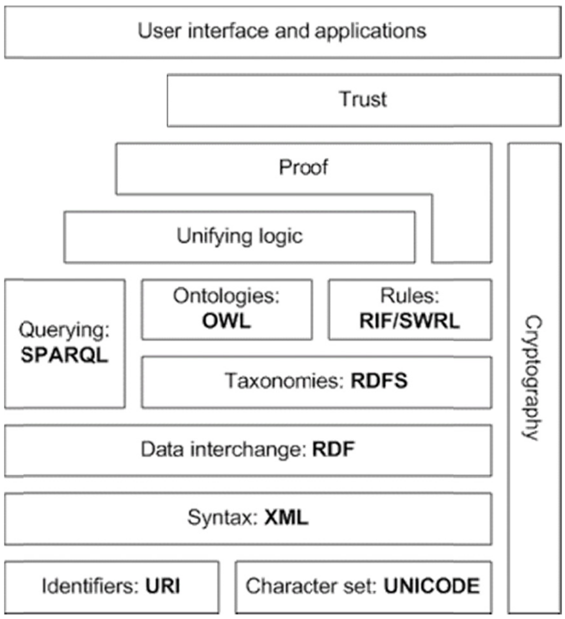

Figure 1: Semantic Web Stack (Obitko 2007).

The Semantic Web Stack basically consists of three layers which are still in development:

1. **Hypertext Web Technologies:** *Uniform Resource Identifiers (URI)* provide a clear identification of resources (e.g. HTTP, FTP or e-mail addresses) within the World Wide Web. *Unicode* is an international standard character set eliminating incompatibilities between different languages and countries. With the *Extensible Markup Language (XML)* text data can be represented in a hierarchically structured

form. The primary benefit of XML is to provide a platform, programming language and operating system-independent exchange of data between different applications.

2. **Standardized Semantic Web technologies:** the *Resource Description Framework (RDF)* enables the description of (true) statements about possible resources in the form of a directed graph, which is formed by subject-predicate-object triples. Through this formal representation, the information described and evaluated are machine read- and understandable. *RDF Schema (RDFS)* provides a basic vocabulary for RDF. Thus, for example hierarchies (taxonomies) are defined by classes and properties. The *Web Ontology Language (OWL)* extends RDFS to describe the semantics of RDF statements. It is based on description logic and enables the use of automated reasoning mechanisms. The *RDF Simple Protocol and Query Language (SPARQL)* is used to retrieve information from RDF-based data (including RDFS and OWL).
3. **Not standardized Semantic Web technologies:** By the aid of the *Semantic Web Rule Language (SWRL)* and the *Rule Interchange Format (RIF)* rules can be defined and exchanged with other rule-based systems. These technologies are especially relevant to relations that cannot be defined by the OWL description logic but only be evaluated by inference at run time. The *Trust* block on top of the Semantic Web Stack attempts to verify statements on their trustworthiness. This on the one hand can happen within the block *Cryptography* e.g. by digital signatures ensuring that information comes from trusted sources and, on the other hand, using formal logic during the investigation of new information within the block *Proof*. For the development of applications within the block *User Interface and Applications* different libraries in diverse programming languages are available by now.

3. BASIC ARCHITECTURE

To describe how a typical crowdsourcing platform architecture will be enriched with semantic technologies, a classical crowdsourcing workflow is shown in Figure 2. The workflow is started by a requester (a company) splitting its scope of work into small Human Intelligence Tasks (HITs) and applying them to the crowdsourcing system. In addition, qualification tests for more complex tasks can be created, which first have to be passed by the interested e-workers to be allowed to perform the corresponding HITs. The HITs are then offered to the e-worker community. It is also possible that the requester assigns HITs to experienced e-workers directly. The solutions produced by the e-workers are processed back to the system and assessed by the requester. If the requester accepts the result, a corresponding compensation is performed in form of money or other output-related incentives.

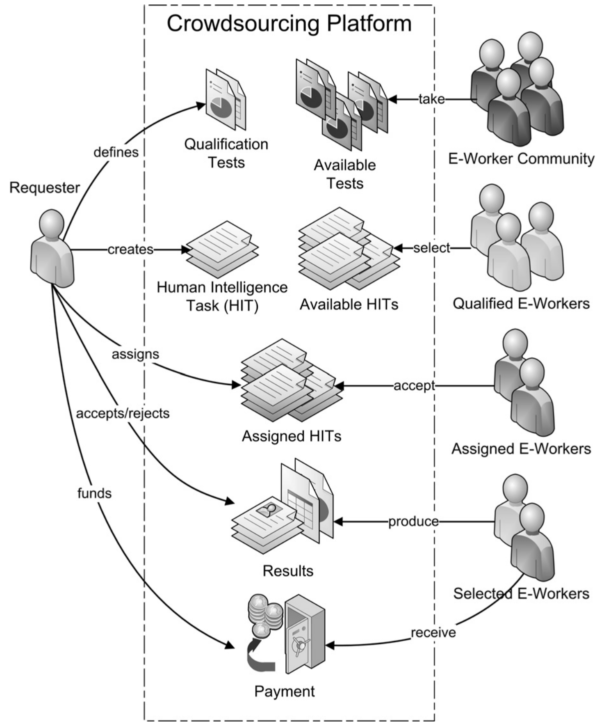

Figure 2: Crowdsourcing Workflow.

Especially for the requester a significant administrative burden arises from managing HITs which can be improved by a pervasive enhancement of crowdsourcing platforms through semantic technologies.

3.1. Semantic Enhancements

The biggest challenge for the requester is to divide complex tasks into separate HITs so that they can be distributed and processed through the crowdsourcing system. Especially workflows, which often have to be performed in a similar, but infrequently in the same way within a company (e.g. the preparation of offers for customers, the procurement of equipment or specific customization of an ERP system) cannot yet be assigned via crowdsourcing, because of the fact that the effort to define, manage and control the HITs and the merging of the individual results would be too big.

In order to make this execution possible and especially to support the requester systematically, an automated creation of HITs based on an adaptable process definition or a set of rules shall be supported. A modelling language called Event-driven Process Chains (EPCs) allows a graphical representation of business processes in principle, but for a further automatic execution it lacks of a semantic specification of the EPC-model elements themselves. The potential to solve this problem arises from ontologies.

According to Tom Grubers definition an ontology is an explicit specification of a conceptualization (Gruber 1993), i.e. an abstract representation of the real world. Ontologies also contain inference and integrity rules. The definition of an EPC-ontology using OWL offers many further advantages such as the possibility to query process models at the semantic level (using SPARQL), the reasoning of new facts by inference mechanisms (reasoners) at query time, or the possibility for user-defined enhancements of existing ontologies to include additional statements and rules (using SWRL) (i.e. to comply with law regulations or to describe technical details of the implementation of a process) (Thomas and Fellmann 2006).

In the same manner HITs resulting from the process can be represented. Their representation should be understood clearly and easily not only by humans (e-workers), but also be offered as automated and targeted as possible to the "appropriate" e-workers (assigned e-workers) to achieve a high quality solution. As a result of these requirements it is necessary to describe both the requirements of HITs and the qualifications of an e-worker, along with other information such as her/his availability, scheduling, etc. in the form of so-called semantic e-portfolios (using RDF/S) . Therefore, in particular the requirements for flexible working hours are taken into account. Even the quality of the results assessed by the requester should be part of e-portfolios, so they can on the one hand be considered in the selection of e-workers and, on the other hand, can be used to perform focused skill trainings for the e-workers, and thus to continuously improve the work environment.

To realize the SEEWOP software as a first step existing crowdsourcing platforms are now being investigated for their suitability and extendibility. Then, the required ontologies to describe the individual knowledge components will be implemented in an iterative development process by the aid of Computer Aided Knowledge Engineering (CAKE) tools and gradually integrated into the selected platform. This knowledge models and the detailed system design will be described in detail in a dissertation in progress and several accompanying publications.

4. SUMMARY

The paper describes the proposed SEEWOP system architecture as a combination of classic Web 2.0 with Semantic Web technologies. The enrichment using annotations, defined by vocabularies and ontologies in RDF/S and OWL, provides a machine-processable description of tasks, job profiles and e- worker portfolios. Processes and rules are defined in OWL and SWRL and can be evaluated at run time by inference mechanisms and SPARQL queries. Together with optional assessments for the results an intelligent management of e-work via a crowdsourcing platform is provided.

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A PARAMETERIZED MODEL OF MULTIMODAL FREIGHT TRANSPORTATION FOR MARITIME SERVICES OPTIMIZATION

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ABSTRACT
Multimodal transport has been promoted by several transport commissions initiatives as an alternative to road transport. A key factor for improving its competitiveness is to provide private and public investors with means for evaluating and selecting the best options in terms of profitability. This paper presents a parameterization schema of a freight transport model for the assessment of a multimodal transport service in terms of its internal rate of return (IRR). Parameterization enables the application of optimization algorithms for the maximization of profitability. In order to verify the proposed parameterization, a case study is presented consisting of the evaluation of a new maritime service for the interregional freight transport in Spain.

Keywords: logistics, freight transport, multimodal, simulation, supply chain, optimization, IRR.

1. INTRODUCTION
Environment and economy are two of the most important issues in the globalised world. Most of the countries promote initiatives to make compatible the ecomomic growth with the protection of environment. The promotion of sustainable modes for freight transport is one of the objectives of the transport commissions. Multimodal transport has received a great deal of attention in the last decades as a feasible alternative for transport by road.

Multimodal transport is presented as a solution for the unbalanced global sharing of the transport flows. As an example, data from the Spanish-French Observatory of the traffic in the Pyrenees shows (in 2008) a freight flow of 65.9 million tons between the Iberian Peninsula and France. This was shared in 83% by road, 16% by sea and 1% by railroad.

One of the most important initiatives in Europe for the promotion of multimodal transport is the European Transport White Paper (2001). It describes the necessary measures to obtain a sustainable European transport in 2010: promoting a balanced growth of all the transport modes and paying attention to the multimodality of the modes. The development of the MARCO POLO programme, the promotion of Short Sea Shipping and Motorways of the Sea, the improvement of connexions between ports and railroad and the improvement in service quality are the main goals of the European transport policy in order to reach the objectives of the White Paper, especially for freight transport.

In 2011 a new Transport White Paper has been published. It reinforces the need of the multimodal transport and the implementation of actions to support it. One of them is the optimization of the multimodal chain performance in different terms (raising flows, energy efficiency, profitability, etc.).

The goal is to achieve a freight flow from road to other modes in a percentage of 30% in 2030 and 50% in 2050. To do so, efficient and ecological freight corridors and investments in infrastructures have to be promoted. EU proposes to enhance the attractiveness of multimodal services for the shippers in terms of profitability. In Spain, the Strategic Infrastructures and Transport Plan supports the development of multimodal infrastructures or services. It also promotes the cooperation between all the elements of the multimodal chain, setting out the possibility that Spain could be an international logistic platform.

Therefore, the EU needs freight corridors specifically developed to ensure a high uptake of the flow of goods. Competitive, reliable and safe routes would attract the investor and also respect the environmental rules on energy efficiency and emissions. This context provides an ideal framework for the development of initiatives for the optimization of multimodal transport chains.

The model presented in this work takes into account both motivations, i.e. multimodal freight transport services design and its assessment profitability (public or private developers). An appropriate definition of the parameters of these services is needed for the application of optimization algorithms.

In the first part of the paper a brief review of transport simulation and optimization is provided. Then, the developed model is presented.

2. STATE OF THE ART.
From the point of view of optimization, most of transport planning problems (VRP, network design,

route planning, etc.) are combinatorial optimization problems, notoriously difficult to solve. Transport models can be divided in those concerning passengers or freight. Bielli, Bielli and Rossi (2011) concluded that transport and logistics service requires the collaboration of different disciplines due to their special characteristics. They explained the need of combining data mining, forecasting methods, optimization and simulation models, heuristics, etc. in a useful decision system.

The case of Passenger Transport Modelling has been widely studied, using generally the Classical Model of the Four Stages (De Dios and Willumsen 2011). This method requires network modelling (graphical and operationally) and transport. Although this model can be adapted for the carry of goods, it often fails due to a lack of definition on policy makers' preferences (by the limited availability of data). Specifically, Kreutzberger (2008) identifies four parameters that are usually characterized, namely the cost of transported goods, transport reliability, frequency of shipments and transport time.

Unlike passenger transport, the consideration of the carried goods (transported unit and level of disaggregation) is a decision that influences the transport system design. If the study is focused on a specific sector, it may be of interest to restrict a very specific type of goods. For instance, in Gursoy (2010), only the goods in the textile sector are studied. Multimodal freight transport models are complex systems composed of different transport networks, infrastructure, different media and transport operators, which further increases the number of possible combinations. Regarding the type of merchandise, both the same unit for all modes of transport is defined in the model or other variables such as media storage and loading / unloading operations have to be included. In this work, the container has been adopted as the homogenous transport unit used for goods with high added value. This assumption has been considered convenient since containerized freight is easily transferred between transport modes and thus suitable for multimodal transport.

There is abundant literature on the field of simulation and optimization applied to transport modelling. The majority of previous papers are limited to the analysis of a single mode of transport. Fagerholt et al (2010) present a methodology for strategic planning of a shipping company. The simulation is performed by solving the route planning time considering a "rolling horizon" where information is updated. In the long term, the solutions can solve strategic problems on fleet size and terms of contracts. Chou, Song and Teo (2003) raised the problem of optimizing shipping routes where there are two types of problems: the direct service and the transfer service. Mu and Dessouky (2011) presented their work to optimize the time plans for rail transport. They combine local search heuristics to find optimal feasible solutions in the short term with a heuristic that optimizes the overall total delay.

A noteworthy example in problem solving multimodal transport is the work of Yamada et al (2009). This work optimizes a particular network of multimodal transport for the exchange of goods. On the other hand, Andersen et al (2009) present an optimized model for tactical design of service networks for several companies, with special attention to the effect of timing and coordination of services as parameters for improvement.

Our work proposes the development of models of multimodal freight transport with a focus on simulation and optimization. Unlike the previous works outlined above, this model does not distinguish the freight by its nature but uses an aggregate unit. Another difference is that restrictions on sending terminal or fixed destination are not assumed; their choice is part of the solution of the optimization (the definition of routes) and the individual decision process of the network users. This is a computationally expensive optimization problem because of the size of the modelled networks as the number of variables and relationships between different modes listed as alternatives increase. Also, considering the economic aspect is less common as a criterion to optimize transport problems.

Some studies in Spain (Romero–Hernández 1999) in medium cities show the positive influence of improving the communication roads of the city. The investment valuation techniques that have been traditionally employed are based on static net present value (NPV static). However, the employment of his technique for the assessment of long term and complex projects is now seen as incomplete, rigid and myopic, and often leading to major deviations (Romilly 2004).

The freight transportation problem is complex in its a priori definition, and it has wide horizons for planning, implementation and operation. Extended NPV based on real options are best suited to dynamic projects with high uncertainty, as it is the case.

Real options assessment (ROA) has been successfully used in sectors like pharmaceuticals, energy and aeronautics. However, applying this methodology in the field of logistics simulation is an original and promising approach.

Although not yet accomplished, the parameterization schema and the transport model explained in this paper are the first steps in order to obtain the complete simulation model that will allow applying ROA algorithms and optimization algorithms based on typical NPV or Real Options NPV.

3. METHODOLOGY.

As it was said in introduction, this work seeks to parameterize a multimodal freight services model in order to apply optimization algorithms. The new service modelled is parameterized in terms of a set of design variables that influence the expected return from the point of view of the shipper. To do so, a GIS (geographic information system) and a transport planning software (TransCAD) have been used.

The first step of the work was the construction of the multimodal freight transport model. This work extends the model of Spanish interregional freight transport developed by Rios et al. (2011). Based on the classical four steps method, it allows the evaluation of flows absorption between road and multimodal options. It was observed that the transport characteristics (fees and times) lead to variations on the absorption of freight flows by the multimodal option.

In the second step, design variables of a new maritime transport service were defined together with the parameters for the profitability calculation. The transport model is used to forecast future multimodal flows and thus to estimate the discounted cash flow of an investment option in the designed service. The span of the simulation was 10 years. Available data were used to verify the model definition and implementation in TransCad and to demonstrate the utility of the proposed parameterization.

3.1. Multimodal Transport Model.

The classical four step model was used to develop the transport model. The four steps of the model are Trip Generation, Trip Distribution, Modal Split and Assignment. The first and second steps define the freight flows between zones (Traffic Analysis Zones, TAZ). The third one splits the flows between unimodal and multimodal transport. The last one assigns the flows to the network stretches.

In this case the TAZ chosen were groups of council clusters (with identified functional relationship between the councils) gathering population levels high enough for generating and attracting flows of goods. Figure 1 shows the TAZs of the model. Data from the National Statistics Institute (Spain) were used to obtain the freight flows between TAZs.

Figure 1: TAZs of the Model. Multimodal Options between the Spanish Atlantic and Mediterranean Shores were considered.

The method applied in the Modal Split step was logistic regression (Equations 1 and 2). The probability of multimodal transport choice (Equation 1) is modelled as a function of a relative utility measure that depends on the ratio between costs and times for both modes (Equation 2).

$$P_n(MM) = \frac{1}{1+e^{U_n}} \quad (1)$$

$$U_n = -3{,}9848 + 1{,}1606\frac{C_{nR}}{C_{nMM}} - 3{,}7944\frac{T_{nR}}{T_{nMM}} + 8{,}955\frac{C_{nR}}{C_{nMM}}\frac{T_{nR}}{T_{nMM}} \quad (2)$$

In this context, the cost term refers to the door to door cost for the user of the transport service. Thus, it will be the fare charged to the owner of the freight for the transportation of a container from the origin to the destination point depending on the mode employed. Also, the term time refers to the door to door travel time when using each mode. The time and cost calculation will be explained in more detail in the parameters definition section.

The model employs a GIS network containing the main roads of Spain. The maritime legs had to be purposely developed for this research work. This model was used to obtain the future freight flows under different conditions. The simulation has a span of 10 years, which is a common period of time when assessing the Internal Rate of Return of transport services.

3.2. Model Parameters.

The objective function is the profitability of the service (new multimodal route) of a potential shipper. The parameters are the design variables that influence this profitability, such as the ones related to intermediate stops, fees and frequency. In particular, we have considered the following variables:

- **Fare**: Value per TEU and distance. Each route has a particular fare. A condition is imposed in that this fare must be higher than the route cost; otherwise the route would generate losses. Fare affects the flow absorption by entering in the equation 2. Thus, it determines the service incomes which are calculated as the product of the freight flow by the fare applied to each container.
- **Cost:** Both fare and mode option depend on the cost of the service, so it is important to obtain a well fitted cost function. Three possible costs are considered, depending on the link of the transport chain (Equation 3). These costs are the same used to fit the transport model. Road unit cost term is described in Table 1. Costs of the time that the truck is in movement and the time that the driver has to rest have been included (which also depend on the origin-destination distance $\boldsymbol{d_{ij}}$). On its part, inventory cost is an opportunity cost of the TEU, and depends on $\boldsymbol{d_{ij}}$ and truck speed $\boldsymbol{v}$, in kilometres and kilometres per hour respectively.

$$Costs = Cost_{Road} + Cost_{Harbour} + Cost_{Sea} \quad (3)$$

Table 1: Road Cost Functions.

Item	Function	Unit
Unit Cost	$C_{ij} = 1.221 \times d_{ij}$	€
Inventory Cost	$C_{Inventory} = 0.0764 \times 2.7483 \times \frac{d_{ij}}{v}$	€/TEU

Table 2: Harbour Cost Functions.

Port operation Cost	$C_{po} = 22{,}2925 \times GT^{0{,}8448}$	€/stop
Inventory Cost	$C_{Inventory} = 0.0764 \times T_{po}$	€/TEU

The costs on harbour are showed on Table 2. These costs depend on the gross tonnage of the ship, ***GT***, and the port operations times, $\boldsymbol{T_{po}}$, due to the loading and unloading operations and transhipments.

The maritime costs are shown in Table 3. They are calculated following the methodology used by the Spanish Freight Road Transport Observatory (2012). They take into account the financial cost, maintenance, crew, fuel consumption and port fares. These functions depend on ***GT*** , distance between ports $\boldsymbol{d_m}$ (in miles) and ship speed ***v*** (in knots).

Income: Income will depend on both the considered starting and destination points as well as on the freight flow between TAZs.It accounts for the total amount of money that the company receives due to the total number of TEU (freight flows) that moves in a route. However, there may be routes with intermediate stops, so the turnover is the sum of the goods that targets the middle and the end points.

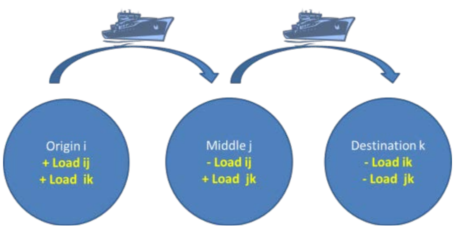

Figure 2: Example of a Route with Intermediate Stops.

Table 3: Maritime Cost Functions.

Capital	$C_{Capital} = 0.4228 \times GT$	€/day
Maintenance	$C_{Maintenance} = 0.0148 \times GT$	€/day
Crew	$C_{Crew} = 386.217 \times GT^{0.1371}$	€/day
Port Fares	$C_{Port\ Fares} = 1.521 \times \frac{GT}{100} + 53.96 \times$ $0.3307 \times GT^{0.8448}$ $+0.85 \times \frac{GT}{100} + 0.03 \times 14.4 \times$ $0{,}3307 \times GT^{0.8448}$ $+5.0759 \times GT^{0.4154}$	€/stop
Fuel	$C_{Fuel} = 0{,}1457 \times GT^{0{,}5081}$	€/miles
Inventory	$C_{Inventory} = 0.0764 \times \frac{d_m}{v}$	€/TEU

Thus, as shown in the Figure 2, for routes with stops, we should also consider the goods from the TAZ ***i*** to intermediate TAZ and goods from TAZ ***j*** to TAZ destination.

The main disadvantage of the routes with stops, are the high costs of each stop in port. The port charges, together with the time wasted between unloading and loading of goods, may contribute to discard the maritime route compared to the road alternative.

- **Intermediate Stops**: They should be considered in solving the problem because they are associated with obtaining the shipping costs.
- **Time**: It is the time from origin to destination. In most cases this parameter is critical for the company that hires the shipping services in choosing one alternative or another. If there are intermediate stops it is necessary taking into account the load and upload times in port. The time for the road stage takes into consideration the time in movement and the time on rest. (Equation 4). d_t is the distance in kilometers between origin and destination and v_t is the speed of the truck in kilometres per hour.

$$T_{road} = 2{,}7483 \times \frac{d_t}{v_t} \quad (4)$$

The maritime time is a function of maritime distance (d_m $in\ miles$) and speed of the ship (v_m $in\ knots$).

$$T_{maritime} = \frac{d_m}{v_m} \quad (5)$$

The time in port depends on the number of stops, N_s, and the time a TEU awaits at the port for being loaded on the ship, the residence time, T_{res}.

$$T_{port} = N_s \times T_{res} \quad (6)$$

T_{res} is proposed as half of the frequency (F, in trips per year) time:

$$T_{res} = \frac{365 \times 24}{2 \times F} \quad (7).$$

It accounts for the time a TEU spends on port waiting for the next call, including the time for port operations. This is quite a rough estimate, which indeed penalizes the multimodal option against the road-only one.

- **Number of Routes**: Due to the number of ports and the geographic dispersion, it could be more profitable to have several routes to transport goods. Two routes may serve different sides of the shore and it may be goods interchange between the routes. Thus, another variable to consider is the number of routes.
- **Number of Ships**: Another possible solution would be to have more than one ship on the route, thereby minimizing the time that the TAZ would have to wait to receive two consecutive deliveries.

$$N_B = \frac{\frac{d_m}{v_m}}{F} \quad (8)$$

Where d_m is maritime distance, v_m is ship speed and F the frequency.

3.3. Objective Function.

After defining the variables involved in the problem, the next step is to calculate the cash flow for the simulation span (10 years). Then, an economic analysis to check the profitability of the route can be performed. To achieve this end, we calculate the Internal Rate of Return (IRR) as follows:

$$Fare = Costs + Net\ Profit \quad (9)$$

$$Income = Fare\ \times Freight\ Flows \quad (10)$$

$$Profits\ Before\ Taxes\ = Income - Costs \quad (11)$$

$$Profits\ After\ Taxes\ = (Income - Costs) -\ Taxes \quad (12)$$

$$Cash\ Flow = Profit\ After\ Taxes + Amortization \quad (13)$$

$$CF_0 + \frac{CF_1}{(1+r)^1} + \frac{CF_2}{(1+r)^2} + \cdots + \frac{CF_{10}}{(1+r)^{10}} = 0 \quad (14)$$

Where CF_j denotes Cash Flow in year j, and r is the IRR. As it was previously explained, fare is the price for the loader per TEU. It represents the total cost of moving a TEU between origin and destination and the profit after taxes (per TEU). The Net Earnings account for the decreasing effect of taxes. In our case study the tax rate is the 30% of the profits (the common type of the Spanish Corporate IncomeTax). The amortization of the ship is the annual cost of the ship during its life time due to its initial and residual cost. A life time of 20 years and a 15% of residual cost were supposed in the case of study.

3.4. Implementation and model execution

The software used to implement the transport model is TransCAD which fully integrates a Geographic Information System (GIS) and planning transport tools. It also provides a proprietary programming language, GISDK, which allows developing of customized transport planning methods by means of macros programming.

In this case, transport network data are stored in the layers of a GIS map and freight flow data in origin-destination matrices. A GISDK macro has been coded that estimates the internal rate of return for a given solution in terms of route configuration and fares. The decision variables are:

- Number of routes.
- Ports and sequence of ports in a route.
- Fares.
- Number of ships.

The macro uses as an argument the previous information. Then, it estimates the freight flow in each route stretch by means of the above presented transport model. Finally, the cash flow is estimated and the IRR calculated. The next procedure is followed for each pair of origin-destination pairs:

1. Time and cost of the road transport mode is calculated by means of equations presented before. Built-in functions allow for the calculation of the shortest path distances between pairs through the road network.
2. In order to calculate the cost and time of the multimodal option, first of all, the closest port to the origin TAZ is obtained. Then, for all the maritime routes that include this port, the one which includes the closest port to the destination TAZ is selected. The total cost for the user of the multimodal service is computed as the sum of the road link (origin to port and port to destination) and the maritime link. The total travel time is computed in an analogous manner.
3. Once the cost and time of each mode have been evaluated, equations 1 and 2 are employed to calculate the fraction of flow absorbed by the MM mode.

The income for a given route is calculated by adding up all the flows absorbed by each route (for all the origin-destination pairs). The calculation is repeated for the origin-destination matrices for each single year of the time span and thus the incomes of the cash flow can be obtained. After that, the costs of the service for every year are calculated. The macro checks that the occupation of the ship is lower than 100%, otherwise the number of ships for the service will be accordingly increased. Once incomes and costs are known, and also the initial investment, a macro calculates the IRR.

4. CASE OF STUDY

From the model implemented in TransCAD the results that show the main characteristics of the service are obtained, i.e., the occupation of the links of the net, the cash flow distribution, the number of moved TEUs and the IRR.

In order to demonstrate the capabilities of analysis, a service with two routes is evaluated. The first route was aimed to link the ports of Barcelona, Valencia, Cádiz and Avilés (R1) whereas the second route linked Castellón, Cartagena, Huelva and Barcelona (R2). Table 2 presents the values of two of the parameters of the model, used to obtain the profitability of the two routes proposed.

Table 2: Data for the Model.

	Frequency	Fare
Fixed Data	50 trips/year	0.50 €/km

Table 3: Route 1 IRR Results.

Barcelona Valencia	Valencia Cadiz	Cadiz Avilés	Avilés Barcelona	IRR Route 1
--	7.30%	9.08%	0.93%	-6.54%

Table 4: Route 2 IRR Results.

Castellón Cartagena	Cartagena Huelva	Huelva Barcelona	Barcelona Castellón	IRR Route 1
--%	-6.46%	12.29%	-19.00%	-11.02%

As incomes and costs depend on the number of TEUs moved in a certain route, a first step is the calculation of the TEUs moved in every stretch of the route. The number of TEUs between origin and destination is calculated applying the Mode Choice Model of the developed transportation model. It gives the probability of taking the multimodal option considering the cost and time of the freight. Figure 3 shows the percentage of occupation of the route, which informs about the extent of use of the ships in this route. For example there are two ships operating the Barcelona-Valencia route reaching an occupation between 90% and 100% during the whole timeframe.

Applying these probabilities to the O-D matrices (matrices of the total number of TEUs between origin and destination) we have the total freight flow that chose the multimodal option. Figure 4 shows the annual multimodal freight flows in TEUs, for the first route of the case of study.

Figure3: Occupation Percentage of Route 1.

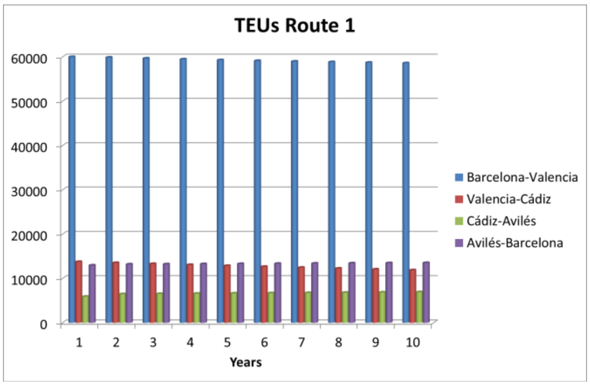

Figure 4: TEUs moved in Route 1.

For this case study we supposed that the initial investment is the cost of the ships of the service. As we are taking into account a generic approach, we disregard any financing method. There are a lot of shipping companies each with different operational set ups, so some of them might not even use external financing. In our case, we assume that the cost of investment will be borne by the shipping company.

The life time considered for the ship is twenty years, which is twice the period of time considered for the profitability assessment. Therefore the residual value of the ships is accounted as an income in the last year of the period. Figure 5 to Figure 8 show the values of Incomes, Costs and Cash flows calculated as they have been explained in point 3 of the paper.

As we can see in Figure 3, Cádiz-Avilés and Avilés-Barcelona are the routes that increase their freight flow over the years. Both routes also give the best results in terms of Cash Flow (Figure7 and Figure 8).

Tables 3 and 4 exhibit the results of applying the parameterization model to both routes R1 and R2. It is important to note that these routes are based on actual operating general purpose routes –thus, timetables, frequencies, stops and other operational parameters have not been specifically design for the optimal exploitation of the routes in terms of multimodal transference- so the IRR values may seem not good enough. But the proposed parameterization is useful to obtain the profitability of the route and the stretches that belong to it.

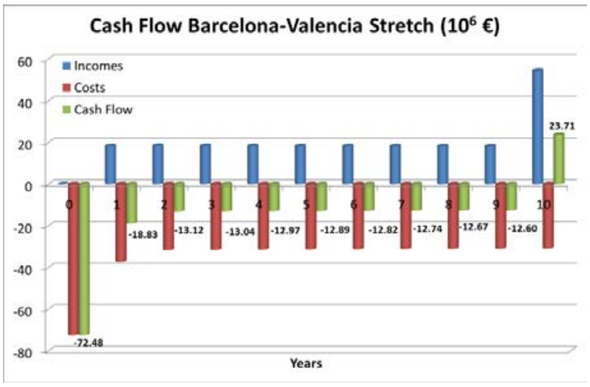

Figure 5: Cash Flow for Barcelona-Valencia.

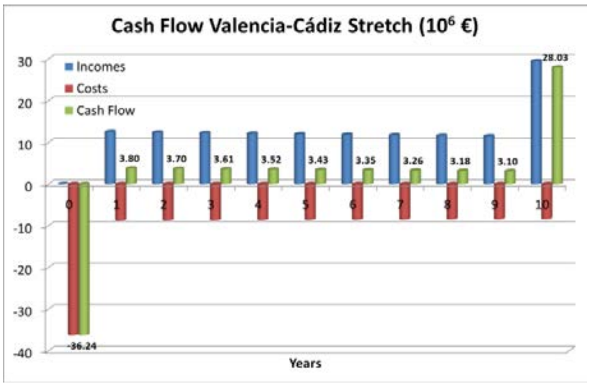

Figure 6: Cash Flow for Valencia-Cádiz.

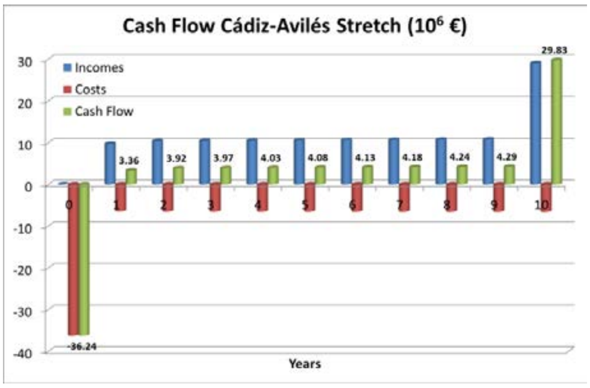

Figure 7: Cash Flow for Cádiz-Avilés.

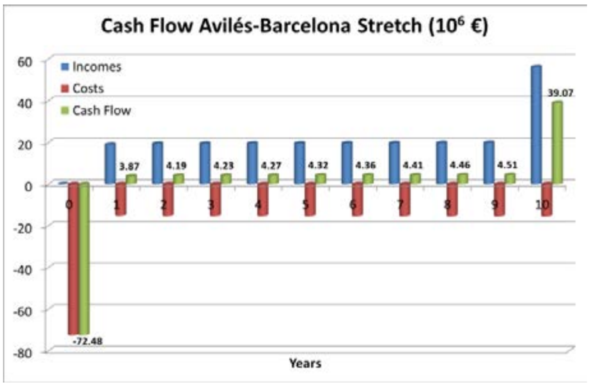

Figure 8: Cash Flow for Avilés-Barcelona.

5. CONCLUSIONS

The assessment of multimodal transport services against road transport in terms of their internal rate of return is achieved thanks to the development of a valid parameterization schema both for the multimodal transport model and for the evaluation objective function. It puts the bases of new IRR optimization algorithms, and as a result, the proposal of new interesting exploitation multimodal services. This is the first step to obtain optimized multimodal routes for freight transport which carry out the objectives of the White Paper of the Transport. The developments of the parameterization together with the transport model also allow obtaining the operation conditions that increase the freight absorption rate of the multimodal mode. So we have the possibility of implement algorithms for a double optimization, i.e., absorption rate and service profitability.

Another important point to take into account is its versatility. In spite of a specific software has been employed to develop the model, the approach and methodology are generic and do not depend on it, so any software that allow displaying GIS networks and implement some transport utilities could be used.

6. FUTURE RESEARCH

A first line of future work is focused on the improvement of optimization algorithms for multimodal services, which is on the original roots of this work. In addition, despite the IRR has been employed as a measure of utility, optimization algorithms should also take into account the possibility of a more flexible kind of assessment, like the ROA (Real Options Assessment).

Although improving the Mode Choice Model really does not have influence on parameterization, it may improve the results of the optimization. Obtaining an improved fitted decision function that better represents the shippers choices would increase the future freight flows estimate and so the IRR values.

Last, but not least, as the availability of data is the key factor in transport simulation, future collaborations with shipping companies that provide the necessary data to develop better models would eventually improve the results of the complete model.

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MODELING AND EVALUATION OF IDS CAPABILITIES FOR PREVENTION OF POSSIBLE INFORMATION SECURITY BREACHES IN A WEB-BASED APPLICATION

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ABSTRACT
Nowadays with vast growing amount of network information systems and their integration not only into work but also into people's private life assuring security of industrial and private information assets is becoming extremely sensitive and topical issue. There is huge number of available free-ware and paid methods of information protection from unauthorized access by unwanted individuals. Currently significant attention of researches in the field of information security is focused on using various intellectual data mining techniques for building an intellectual information security system. Such security systems roughly (for the purpose of this paper) can be divided into intrusion protection and intrusion detection systems – IPS and IDS.

Keywords: information security, intrusion detection, modeling of IDS capabilities, web-based application

1. INTRODUCTION

In general intrusion protection systems includes any available method or recommendation that prevents attackers from gaining access to secured network, system or information asset. Most common ways to ensure high availability Intrusion protection system is usage of any kind of firewall or anti-virus software. Most commonly known five types of IPSs are – inline NIDS, application-based firewalls, layer seven switches, network-based application IDSs and deceptive applications. Each type of mentioned Intrusion protection system has different level of provided protection. There is no possibility to choose best solution since all of them have their pros and cons. By performing analysis of the way each IPS works it's possible to define which exact one would fit best for your needs. Sometimes it's even advisable to build an IPS containing more than one of previously mentioned solutions. For example one of already broadly used ways is – using a layer seven switch in front of Internet firewall to defend against DoS attacks and known attacks and using application layer firewalls/IPS software or hybrid switch to protect Web servers. Currently other ways are being discovered and tested.

Intrusion detection systems, in turn, may be considered as a type of security assuring method as for information systems as also for computers. Such system should make a comprehensive analysis of gathered information of computer, network or information system activities to proactively identify potential security breaches that might include both attacks from inside and outside of protected perimeter. The underlying reason why intrusion detection systems should be used is relatively straightforward – data and systems should be protected from all information security aspects.

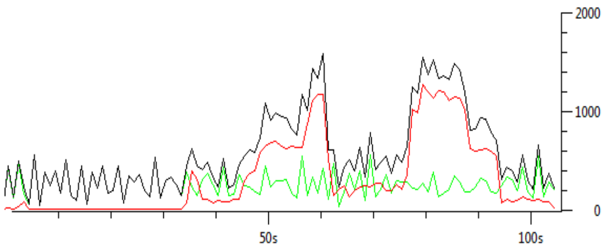

Figure 1: Network activity statistics during DoS attack

Modern Intrusion detection system must be capable of determining level of information confidentiality, integrity and availability (CIA) that are commonly referred as a kind of benchmark for evaluation of information security as such. The fact that data and systems cannot always be protected from outside intruders in modern Internet environment using ordinary security mechanisms such as password and file security, leads to a range of issues. Further measures beyond those normally expected of an intranet system should always be made on any system connected to the Internet. Intrusion detection takes that one step further. Placed between the firewall and the system being secured, a network based intrusion detection system can provide an extra layer of protection to that system. For example, monitoring access from the Internet to the sensitive data ports of the secured system can determine whether the firewall has perhaps been compromised, or whether an unknown mechanism has been used to bypass the security mechanisms of the firewall to access the network being protected. Besides that high quality IDS should assure significant level of ability to recognize user policy violations and abnormal activity patterns.

2. TYPES OF INTRUSION DETECTION SYSTEMS

Currently all intrusion detection systems available on the market fall into two categories – Network based systems which are placed in the network nearby system that is being monitored and that examines network traffic and Host based systems which actually run in the system being monitored and that examines activity of monitored system. Most recent type of Intrusion detection systems reside in the operating system kernel and monitor activity at the lowest available level of protected system.

Table 1: Host and network based systems

Benefit	Host based systems	Network based systems
Deterrence	Strong deterrence for insiders.	Strong deterrence for outsiders.
Detection	Strong insider detection. Weak outsider detection.	Strong outsider detection. Weak insider detection.
Response	Weak real-time response. Good for long-term attacks.	Strong response against outsider attacks.
Damage Assessment	Excellent for determining extent of compromise.	Very weak damage assessment capabilities.
Attack Anticipation	Good at trending and detecting suspicious behaviour patterns.	None.
Prosecution Support	Strong prosecution support capabilities.	Very weak because there is no data source integrity.

Network and host-based IDS bring very similar advantages. Both of them are very well fit for outsider deterrence. Network-based systems are able to warn attackers regarding their illegal actions thus working as a buffer for inexperienced hackers showing them that they are not as safe as it seems like. Contrarily host-based systems work on an assumption that people that are aware about constant monitoring of their actions are less likely to commit misuse. And although both type of systems are able to detect vast variety of intrusion actions first are more oriented exactly to network activities while second are able to detect more insider actions. Furthermore both systems can react and even alert security personnel about possible misuse.

2.1. Misuse and Anomaly detection in Intrusion detection systems

Broadly speaking modern intrusion detection systems use techniques that can be divided into two major categories: misuse detection and anomaly detection. Taking into consideration effectiveness of the anomaly detection technique not only against known types of attacks (like misuse detection does by exploiting signature database) but also against new ones, it has become a topical issue in majority of data and computer security researches.

In recent years a vast majority of research activities in the area of anomaly detection have been focused on studying the behavior of programs and the creation of their profiles based on system call log files. Until now, a simple anomaly detection method based on monitoring system calls initiated by the active and privileged processes is widely used. The profile of normal behavior is constructed by enumerating all unique, and related fixed length system calls, which are observed in the training data; in turn, previously undetermined sequences are considered abnormal. This approach has been extended by various other methods. It was suggested to utilize data mining approach to study samples of the system calls and construct small set of rules contained in normal data. During the monitoring and detection, the sequences that violate these rules are treated as anomalies. For example Hidden Markov Model (HMM) can be used – a method for modeling and evaluation of invisible events based on system calls. Later, the idea of analyzing patterns of system calls of fixed length has been further developed, by analyzing patterns of system calls, but of variable length. Furthermore, a new method for intrusion detection, based on the method of principal components has been introduced.

Profiling the behavior of the end user is not less important aspect of data protection than the profiling the software activities. This method is effective in detecting internal attacks that constitute one-third of the corporate system security. In information systems based on UNIX or Linux operating system, the sequences of shell commands are easily collectible and analyzable information, thus being the source material for creating profiles of end users. Besides, the collection of such information does not use significant system resources. On the other hand, taking into account the difference between the behaviors of end users, building of profiles of their activities is a difficult task comparing to building a profile of program behavior. Hackers can even try adapting their behavior to fool IDS systems.

3. IDS SOLUTIONS

Great part of modern intrusion detection methods are directed to proactive analysis of already conducted attacks and creation of new rule sets for detection of next attack of same type on the basis of previously generated rules. Scope and efficiency in such a case will be limited with those rules for specific types of attacks. Nevertheless enormous traffic caused by new attack cannot be detected. Consequently it is crucial to perform fast analysis of anomaly traffic instead of really detailed to make it possible to determine possibility of incoming anomalous traffic. Usually network traffic analysis consists of following basic functions: primitive network traffic data, integration of traffic data and detection of anomalous network behavior. The main concern with network traffic analysis is not the mere traffic counts but the definition which network should analyze traffic features so that actual collecting method and types are determined. Methods for detection of abnormal network behavior are analogous to intrusion detection system. It detects and analyses network traffic that consists of attacks based on network traffic patterns of well-known attacks. Another method for traffic classification is based on modeling of normal behavior of network activities. Both methods require modeling of network traffic and analysis of related functionality for abnormal traffic. Generally well-known tools such as Ntoop are used for traffic analysis. Besides that TcpDump, IPmon and Snort tools can be used.

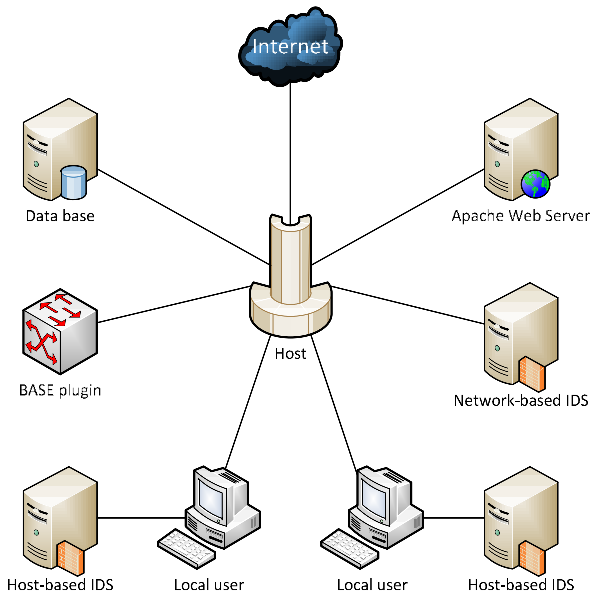

Figure 2: Snort IDS Example

Snort for example is a behavior-based and rules-based NIDS that demonstrates outstanding performance in real-time traffic analysis and packet log analysis. It can be utilized for protocol analysis, examination of packet content, pattern matching, port scan, CGI attacks, buffer overflows etc. It uses very flexible rule language consisting of a module plug-in structure to catch traffic. Three main Snort functions are:

- It can be used as a packet sniffer such as TcpDump.
- Network traffic debugging is available based on internal packet logging function.
- It shows good NIDS functionality. Snort is a packet-sniffing tool that uses the packet capture library of Libpcap.

Snort recognizes sniffed packets and compares them with pre-defined detection rules via a pre-processor and a detection engine to detect an intrusion. Rules for Snort can be easily created by users that later can be applied as a plugin operations with different alert logs and pre-processors. Nevertheless due to simple pattern-matching possibility of false-positives is quite high and detection on new attack types is almost impossible.

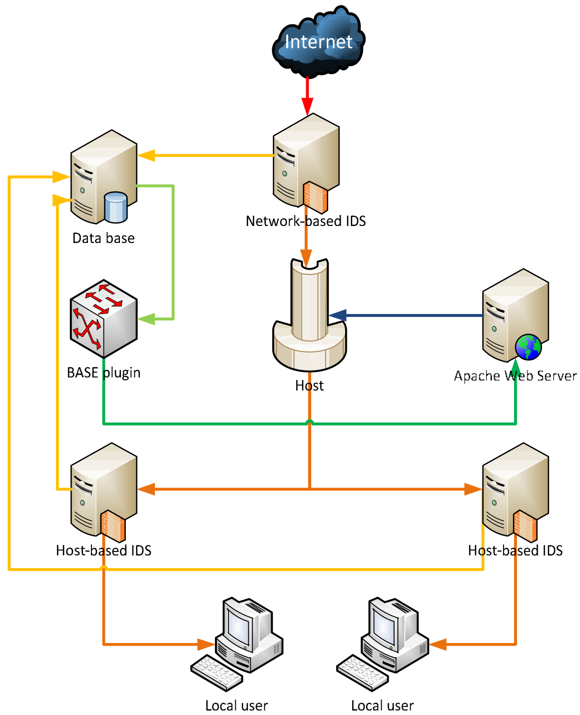

Figure 3: Snort IDS Working Principle

Represents incoming traffic.

Represents filtered traffic inside local network.

IDS traffic to Data base.

Information flow from data base.

Reconstruction of data to HTML/PHP.

Representation of filtered HTML/PHP.

Intrusion detection systems can define abnormal use, misuse, and abuse of a computer system as well as determine the proper action in the event of an intrusion. Although main purpose of intrusion detection system is detection of possible intrusion its' construction also includes active response that is based on current condition of used environment. Normally any Intrusion detection system detects an intrusion by using information from a database and notifies recognized attack attempts to an administrator.

Great part of new researches in the field of intrusion detection focuses on anomaly detection. However, a number of systems still use the detection methods against abnormal behavior similar to misuse detection.

3.1. Role behavior profiling

As it was mentioned earlier behavior profiling is one of the most effective methods for malware attack detection. Modern researches on the modeling of profile are mainly focused on the end-user behavior or program behavior. For dynamic environment such a web-based system adoption of end-user behavior modeling, where limited users boast the fixed activities in their daily operations is more suitable. Unfortunately for the web-based system, which is accessed by millions of users for the information every day, creation of a behavior model for each individual user is nearly impossible. Commonly, the designated CGI programs access the database as the middleware between the database and almost all users. Therefore profiling of program behavior is not significantly better either.

On the other hand three-tier architecture associated with databases mainly is set of known applications. Users interact with data base system using various operations that are either authorized by applications or by end-user itself. In any case the activity on the database strictly depends on the privilege of the executors.

In comparison to user profiling, role profiling can show more regular patterns because functions and tasks operate on interrelated data and therefore is a more static set of sequences of operations.

3.2. Logging policies

Enormous volumes of data in raw log files are the bottleneck place for performance and reliability of any Intrusion detection system. To overcome this problem logging policies can be introduced. One of the possible policy implementation is assigning of different levels of logging for different users. For example, Intrusion detection system will trace the most detailed information for the root user, such as remote IP address, their specific actions, etc. and in contrary least detailed information for guest user. Such technique can noticeably reduce response time of IDS, make use of log files more efficient and consequently improve overall performance of whole system.

3.3. Intrusion detection capabilities in encrypted web traffic

As it was mentioned previously usually an IDS is being deployed near the web server and monitors the network activities by performing protocol analysis and pattern matching. In other words, IDS should reconstruct HTTP headers and payload from captured packets, and identify attacks by comparing traffic to signatures of attacks or behavior profiles.

Such mechanisms as SSL (Secure Socket Layer) or its successor TLS (Transport Layer Security Protocol) were introduced as solution for secure communication and data transfer over the Internet. These protocols first of all allow authentication of servers and users and secondly considerably contribute for safeguarding confidentiality, integrity and availability of data. For encrypted traffic simple Intrusion detection systems need a deposited private key. Alternatively they will have to monitor traffic just after decryption.

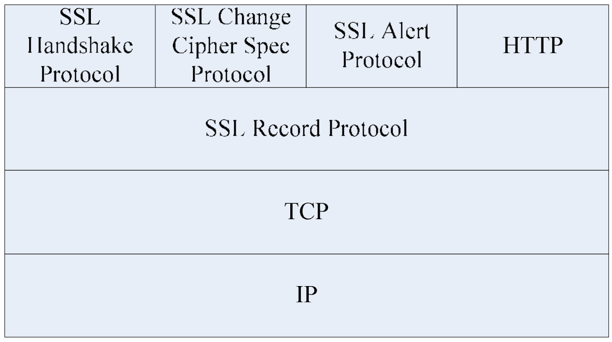

Figure 4: SSL Protocol Stack

These conventional approaches are problematic from the perspective of key management and network configuration and tuning. However such approaches are becoming more and more popular taking into account rising popularity of web systems and application that require secured communication between end-user and server. Thereby web-application server administrators are faced with the dilemma either to provide secured services using SSL/TLS protocols but with less secured system itself because of lack of IDS monitoring or vise-versa.

3.4. Attack types

Currently wide range of attack types against web-application is known. Below most common of them are clarified. It should be noted that such attack classification does not refer to traditional signature based approaches that compare a HTTP request strings to a set of signature strings. Also note that classification makes target clear but it is more abstract class than traditional ones. Usually systems detect such attack classes as: buffer overflow, vulnerabilities of scripting languages and scanning attacks

3.4.1. Buffer overflows

Successful buffer overflow type attack allow malicious user to execute arbitrary code on the web server by overwriting stack or heap memory of the process. Though bounds of memory accesses are usually checked by running programs, unchecked memory accesses allow attackers to crash or even gain full control of a process by sending a larger request or argument. In the worst case scenario attacker can even take control of web server using such vulnerability. It is possible that web applications, modules, and script languages are also vulnerable in this way.

3.4.2. Vulnerabilities of scripting languages.

Biggest part of web-applications uses such scripting languages as – PHP or Perl. Every new version of a sample of code or scripts distributed with above-mentioned languages has known vulnerabilities so they allow attacker to execute harmful codes. Hacker just has to examine which version of script is currently installed on a target server by accessing this script on this server. As soon as vulnerable script is discovered attacker can compromise server security.

Following is an example:

GET /adserver/adxmlrpc.php HTTP/1.0
GET /phpAdsNew/adxmlrpc.php HTTP/1.0
GET /phpadsnew/adxmlrpc.php HTTP/1.0

3.4.3. Scanning attacks

Such attacks start with examination of existence and current configuration of web or proxy server at an IP address. The attacker can obtain information about the web server and/or proxy server by using simple HTTP methods, such as GET, HEAD and OPTIONS. A directory traversal attack, which accesses the parent directory and gains information about the construction of directories and files, is also categorized as a scanning attack. The following HTTP requests are examples of scanning attacks.

GET http://www.smthng.com/HTTP/1.1
HEAD /HTTP/1.1
OPTIONS /HTTP/1.1
GET /HTTP/1.1

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DESIGNING TWO-ECHELON SUPPLY CHAIN USING SIMULATION AND PRICING STRATEGY

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ABSTRACT

In this paper a two- echelon supply chain, including manufacturers and retailers have been considered. We have opened centers for manufacturers and retailers to set; we also considered how to determine the allocation of suppliers to retailers and the order amount of each retailer to maximize the whole profit of the supply chain. Our strategy in this paper is to determine the profit considering the unit price and revenue sharing; we also used simulation to estimate the transportation cost in the supply chain. Transportation cost for each vehicle is regarded with different costs during the loading, unloading and journey events according to discrete event simulation. Defined model for supply chain has been solved by simulating annealing (SA) algorithm.

Keywords: Supply chain, Discrete-event simulation, Simulated Annealing, Pricing

1. INTRODUCTION

A supply chain (SC) consists of all companies involved in the procurement, production, distribution and delivery of a product to a customer. Because different economic entities participate in the SC, it is significantly more complicated to manage than a single organization (Chaharsooghi and Heydari). From an operational perspective, SCM is to effectively integrate suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize system wide cost while satisfying service requirements (Simchi-Levi, Kaminsky et al. 2003).Revenue management is the use of pricing to increase the profit generated from a limited supply of supply chain assets. To increase the total margin earned from these assets, managers must use all available levers, including price. Revenue management adjusts the pricing and available supply of assets to maximize profits. Revenue management has a significant impact on supply chain profitability when one or more of the following four conditions exist:

1. The value of the product varies in different market segments.
2. The product is highly perishable or product wastage occurs.
3. Demand has seasonal and other peaks.
4. The product is sold both in bulk and on the spot market (Sunil 2010).

As supply chain members are often separate and independent economic entities, a key issue in SCM is to develop mechanisms that can align their objectives and coordinate their activities so as to optimize system performance (Li and Wang 2007). Coordination within a supply chain is a strategic response to the problems that arise from interorganizational dependencies within the chain. A coordination mechanism is a set of methods used to manage interdependence between organizations.

Given the increasing importance of high-performance supply, and the advantages to be gained through supply chain coordination, the challenge to an organization is how to select the appropriate coordination mechanism to manage organizational interdependencies (Fugate, Sahin et al. 2006; Xu and Beamon 2006).

Supply chain coordination improves if all stages of the chain take actions that together increase total supply chain profits. Supply chain coordination requires each stage of the supply chain to take into account the impact its actions have on other stages. A lack of coordination either occurs because different stages of the supply chain have objectives that conflict or because information moving between stages is delayed and distorted. Different stages of a supply chain may have conflicting objectives if each stage has a different owner. As a result, each stage tries to maximize its own profits, resulting in actions that often diminish total supply chain profits (Sunil 2010).

Today, in many papers like another paper of same authors in various areas the simulation is used(Kazemi and Taki 2012; Taki and Kazemi 2012). One of the powerful tools is discrete-event simulation (DES) model. Companies and manufacturers can use it to perform analyses to estimate the impact of their decisions performance on the overall before they made any real system changes(Kazemi and Taki 2012).

2. PROPOSED MODEL

2.1. Problem definition

Consider a two-echelon supply chain, including suppliers and retailers; there are some predefined place to set up Suppliers and retailers, supplier (manufacturer) produces the product internally under capacity limits. We have one kind of product and all vehicles are the same, The average cost of transportation depends on travel time, mean of waiting time, and the service of loading and unloading queues. In our simulations, we solve the following four events:

1. The event of traveling from supplier i to retailer j
2. The event of traveling from retailer j to supplier i
3. End of unloading event for j
4. End of loading event for j

2.2. Equations, Figures and Tables

Each open retailer can only connect to one supplier. Demand is a function of price and varies for each retailer linearly. The product unit sales price is the same for the entire chain.

Determining which of i and j are open and their relationship. Determining the product unit price Determining the order amount of any j to i.

Table 1: Notations

Index	
Manufacturers Index (1,2,…,N)	i
Manufacturers Index (1,2,…,M)	j
Parameters	
Dj(P)	Demand function of each retailer
Ci	Unit production cost of producing product i
hj	Iinventory costs per unit of product j for retailer
Aj	Fixed ordering cost retailer j
Qr	Maximum capacity of transportation
Bi	Fixed setup cost of manufacturer i
Ej	Fixed setup cost of retailer j
CAPi	Production capacity of i
Decision Variables	
Xij	Existence or nonexistence of communication between manufacturer i and retailer j
Ui	Manufacturer i is open or closed (1 if it is open, otherwise 0)
Vj	Retailer j is open or closed (1 if it is open, otherwise 0)
P	Product unit sales price (fixed value for the entire chain)
Qj	Order of each retailer
Mij	The transportation costs per unit for transportation from manufacturer i to retailer j (It is obtained by DES)

Demand is a function depending on the price and defined for each retailer as:

$$D_j(P) = \begin{cases} \alpha_j - \beta_j P & 0 \le \mathrm{P} \le \alpha_j / \beta_j \\ 0 & \mathrm{P} \ge \alpha_j / \beta_j \end{cases} \qquad (1)$$

Objective Function.

$$Max f = \sum_{j=1}^{N} P D_j(P) V_j - \sum_{i=1}^{M}\sum_{j=1}^{N} C_i D_j(P) X_{ij} U_i V_j - \sum_{j=1}^{N} h_j \frac{Q_j}{2} V_j - \sum_{j=1}^{N} A_j \frac{D_j(P)}{Q_j} V_j - \sum_{i=1}^{M}\sum_{j=1}^{N} M_{ij} \left\lceil \frac{Q_j}{Q_r} \right\rceil \frac{D_j(P)}{Q_j} X_{ij} U_i V_j - \sum_{i=1}^{M} B_i U_i - \sum_{j=1}^{N} E_j V_j \qquad (2)$$

Subject to:

$$\sum_{i=1}^{M} X_{ij} \le V_j \quad \forall \mathrm{j} \qquad (3)$$

$$X_{ij} \le U_i \qquad \forall \mathrm{i, j}$$

There is relationship between i and j if they are open, it means Each retailer can only be connected to a supplier but the supplier can be connected to multiple retailers.

$$\sum_{j=1}^{N} Q_j X_{ij} U_i V_j \le CAP_i \quad \forall \mathrm{i} \qquad (4)$$

$$V_j, U_i, X_{ij} \in \{0,1\} \quad \forall \mathrm{i, j}$$

$$\mathrm{P}, \mathrm{Q_j} \ge 0 \quad \forall \mathrm{j}$$

It should be noted that the amount of Qj is determined due to Economical order Quantity (EOQ).

The first term of objective function is the amount of sales, the second is production costs in manufacturer open centers, the third is inventory costs in open retailer centers, the forth is order cost for any open retailer, The 5th is Total transportation cost, the 6th is The cost of setting up manufacturing sites and the last is the cost of setting up retailers.

Mij function for every manufacturer and retailer is obtained from discrete event simulation.

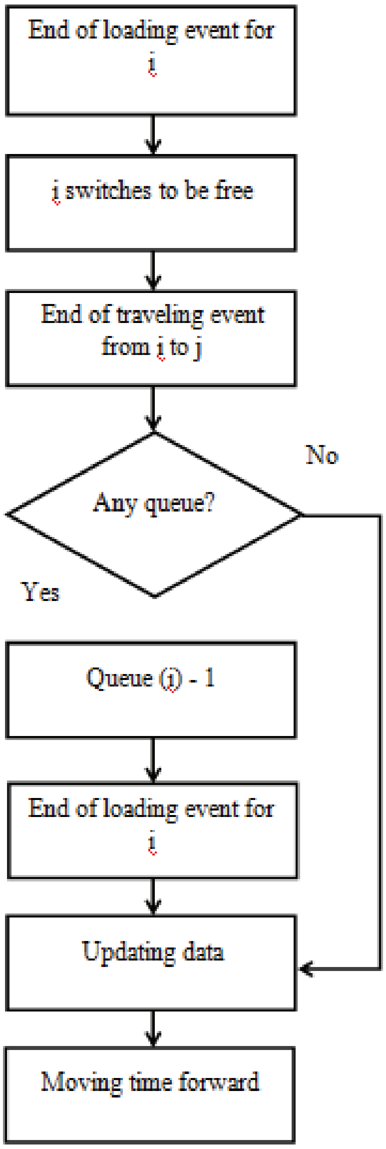

Fig.1 Flowchart of the simulation model for end of loading event

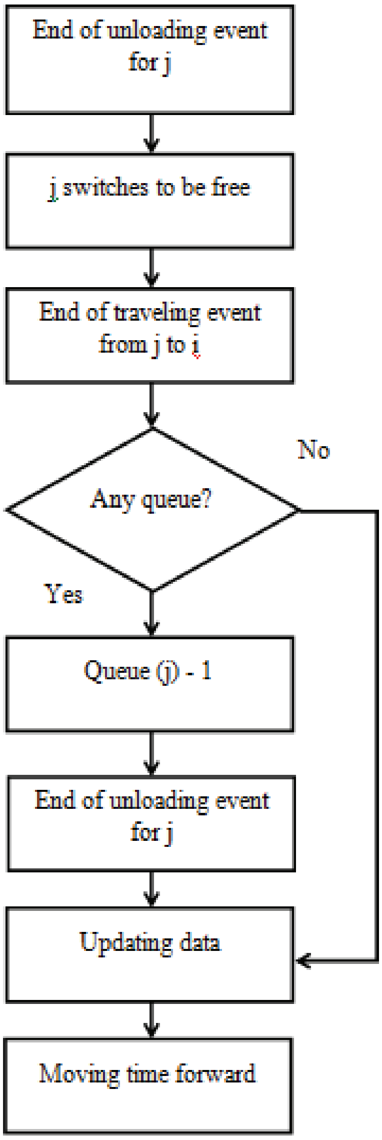

Fig.2 Flowchart of the simulation model for end of unloading event

To obtain Mij :
Loading time in all the manufacturers are the same and have normal distribution with mean of 20 minutes and variance of 5 minutes.
Unloading time in all the retailers are the same and have normal distribution with mean of 15 minutes and variance of 3 minutes.
Traveling time will be divided into five groups with uniform distribution:

- -U(120 min,150 min)
- -U(100 min,130 min)
- -U(70 min,90 min)
- -U(30 min,50 min)
- -U(90 min,110 min)

3. RESULTS

We use SA algorithm to obtain an optimum solution of the objective function. The final result for the first objective was 516357.68.

As can be seen the stable solution is reached. To ensure an accurate answer, we compare the optimal solution with Genetic Algorithm(GA). As you see in Fig 2, the optimizing trend

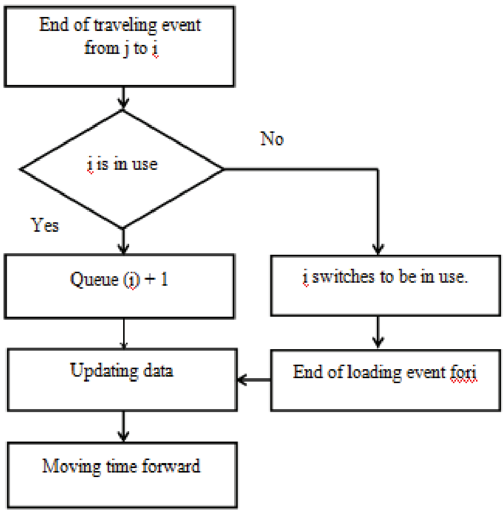

Fig.3 Flowchart of the simulation model for end of traveling event from j to i

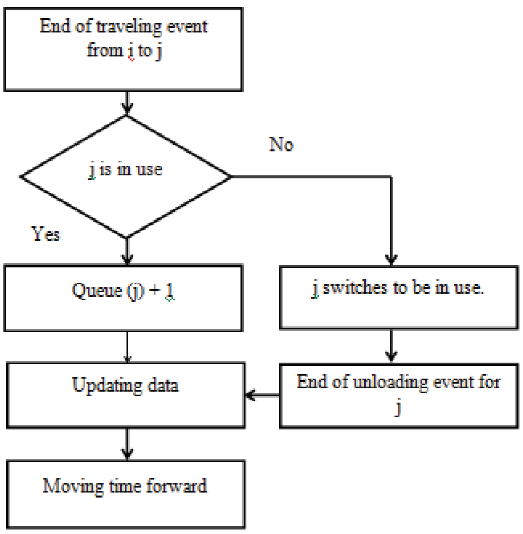

Fig.4 Flowchart of the simulation model for end of traveling event from i to j

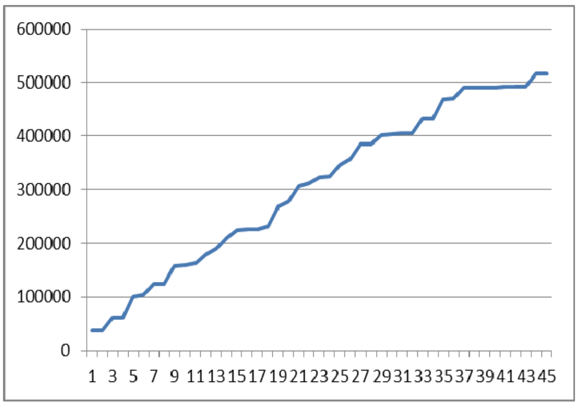

Fig.5 The results of using SA to find optimum solution

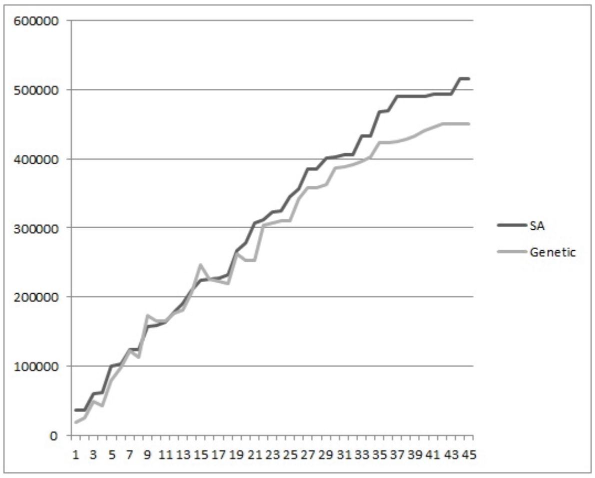

Fig. 6 The Comparison of SA algorithm solution with the Genetic Algorithm solution

4. CONCLUSION

Nowadays, many cases such as disruption, disasters, Perishable materials problem and some other topics are important for supply chain and pricing. In his paper, a two echelon supply chain has been design with regards to a assignment-order-pricing model. It has been considered that transportation cost for each vehicle is not a parameter. Therefore, discrete event simulation is used to evaluate the cost. Due to the important role of risk in supply chain, it is recommended to add risk minimization as an objective function. For next researches, we suggest to use the multi-objective models considering risk as an objective function.

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INTEROPERABLE SIMULATION FOR PROTECTING PORT AS CRITICAL INFRASTRUCTURES

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ABSTRACT

The research proposes an interoperable simulation framework to analyze and investigate security issues in complex maritime scenarios affected by asymmetric threats (i.e. terrorist attacks) with particular attention to people and goods flows in Ports. The main aim is to support both decision makers and trainers in applying operational and organizational security policies and procedures and to assess the impact of these policies on security efficiency in global flows of goods & people. Therefore the proposed framework is useful for the review, testing and certification of Ports Security Plans, Risk Assessments and Gaps Identification as well as for operators training.
Due to the complexity of the Port system including several actors and infrastructures, the operations coordination is critical in order to face new asymmetric threats; so interoperable simulation combined with Intelligent Agents and Data Fusion techniques is an important approach in order to provide a set of simulation models cooperating in the same scenario and to simulate security procedures and policies.
The authors provide a simulation federation to analyze and test security procedures and regulations by proposing a case study based on the collision of two hijacked ships within the port.

Keywords: Port Security, Interoperable Simulation, Intelligent Agents, Computer Generated Forces, Data Fusion.

INTRODUCTION

Considering new asymmetric threats such as terroristic and cyber attacks, fire explosions on board, shore fires, on-water spillage and environmental incidents within the port, Port Protection and Security are becoming very critical issues for the global maritime context (Alberts et al. 2000). In particular after the 9/11 terrorist attack, the security became suddenly the main problem for people and for the supply chain management, instead of the speed and efficiency of international trade and travel (Bruzzone 2010).
In effects international regulations and procedures are provided, such as:

- January 2002 Container Security Initiative (CSI)
- November 2002 Maritime Transportation Security Act of 2002 (MTSA)
- December 2002 International Convention for the Safety of Life at Sea (ISPS)
- July 2004 International Convention for the Safety of Life at Sea (SOLAS).

Therefore it is fundamental to assess critical situations and threats and to test different procedures and solutions (Bruzzone et al. 1997, Bruzzone et al 2010). Modeling and Simulation allows to reproduce different maritime scenarios involving several entities and actors (Merkuryev et al. 1998). In effect a Port is a complex system involving a large number of entities dynamically interacting in an open environment 24 hours/day 365 days/year (i.e. Coast Guard or Navy, Port Authority, Terminal Operators, Shipping Companies, Custom and Border Protection Agencies and other institutions).
Obviously, it is fundamental a good interaction and coordination among all the involved actors and facilities to successfully identify and respond to the threat; for this reason, new technologies and solutions are necessary to train operators and to test different security procedures and regulations without the block of port activities.
In addition a terrorist attack or and incident within the port could affect these actors and the whole logistic network which the port belongs, having a strong impact on global shipping and international trade as well as on port military strategies and local logistics and transportation system (Bruzzone et al. 1996). So, Security policies and procedures have a big impact on the transportation system. It is evident that if physical inspections (i.e. container scanning, gate controls, custom checks, etc.) are increased, it is possible to bring international trade to a halt or loose

competitiveness versus other countries. In this context, research should provide innovative solutions and technology to be applied to security procedures and operations (Bruzzone, Page & Uhrmacher 1999).
The authors propose a synthetic environment based on interoperable simulation models, combined with Intelligent Agents for Computer Generated Forces, in order to support Port authorities, Port safety officers, Vessel commanders, shipping companies and other departments (dealing with port issues) in analyzing and testing security plan and procedures and even in designing new ones (Bruzzone et al. 2005). In addition, this simulation should aid decision makers to quantify the trade-off between achieving security goals and their costs, as well as discovering improved procedures in order to optimize the performance of security systems, including all port activities and processes (i.e. material handling, data communication, human procedures, business processes, etc) (Curcio & Longo 2009).

1. THE SCENARIO

Port Protection is very difficult due to different factors:
- Its extension and size
- The excessive access ways, often not adequately monitored
- Lack of coordination and communication among different terminal operators that are assigned to protect different areas and docks
- Ferry and cruise terminals are open to the public
- Baggage are not always inspected on ferries
- Entrance is permitted also to un-authorized persons (passengers, suppliers, crews)
- Boats and tourism facilities are in close contact with operative areas
- Cargo handling involves check procedures and documentations that slow down operations

In the last years different threats and incidents are spreading including:
- Thefts
- Smuggling
- Narcotics
- Terrorism
- Fraud
- Clandestine individuals
- Vandalism
- Organized crime
- Environmental crime

To prevent and detect these threats it is necessary to focus on regulations and standards, organization and procedures and personnel training in order to proper react by taking into account (Fischer & Green 2003; Liddy 2005)
- Threat Intensity
- Alert Levels
- Inspections
- Planning
- Operative Support control

These standards introduce actions and preventions to be carried out in order to improve port security:
- inspections to protect global trade system
- intelligence use and automated advance targeting information to identify and target containers that pose a risk for terrorism
- Prescreening those containers that pose a risk at the port of departure
- Improve communication among law enforcement officials responsible for port security
- to invest in long-term technology
- to increase intelligence collection on cargo and intermodal movements
- to conduct vulnerability assessments and develop security plans that may include passenger, vehicle and baggage screening procedures; security patrols; establishing restricted areas; personnel identification procedures; access control measures; and/or installation of surveillance equipment.

2. M&S FOR SECURITY IN MARITIME CONTEXT

Modeling & Simulation provides a very fundamental support to Port Security in different application areas:
- Architecture/Infrastructure/Procedure Design
- Training
- Testing New Solutions
- Standing Operation Planning
- Operative Support & Emergency Management

In addition M&S supports port authorities to improve infrastructure design, control system architecture and operation management by considering security requirements and regulations and to reduce the impact of new threats within reasonable cost and without losing operative efficiency (Sennewald 2003; Longo et al. 2012).
The use of M&S to analyze and improve security within a port is more than justified by the need to analyze complex interactions among numerous factors. The simulation techniques are actually employed to evaluate impacts of the security requirements for people flow (e.g. passenger and baggage screening on port operations performance) and cargo flow. In particular Security equipment and procedures related to logistics facilities are usually grouped into:
- Internal: Security control of logistics flow to ensure that goods are not dangerous (i.e. container scanning, gate controls, custom checks, etc.)
- External: Security control of external component (i.e. terrorists)

In addition it is necessary to consider that the intensive flows of entities (i.e. people, materials, etc.) in logistics facilities have a mutual influence and can be a potential

threat to other entity flows. For instance in port logistics there are several entities, that are potential threat; in this domain, intrusion models could be used to control potential interference between Cargo and people entities in various areas of ports and M&S is often used to study processes, performance levels and costs with regard to regular operating conditions and to support assessments of the impact of safety and security procedures on logistics results (Bruzzone & Giribone 1998). These simulators are also used to test different organizational models within critical structures (Bruzzone 2004).
Several tools are available in the commerce for port infrastructures and logistics simulation (i.e. RescueSim and PortSim); anyway as far as we know, no one of them allows an integrated approach to quantify the economical impact of the different security policies, and to offer a decision support tool to improve security procedures while minimising a cost increment to the production industry.
New enabling technologies have a great potential in the maritime context (Ladner & Petry 2005); for instance communication infrastructures and mobile solutions allows today to distribute information as well as data collection, data processing and decision making over a large complex network and even great benefits are provided by innovative soft computing techniques and methodologies (Anderson, 2006; Bruzzone et al., 2011b,; Bruzzone, Page and Uhrmacher, 1999; Ladner et al., 2009).
In the recent years the authors are studying new models and solutions based on a multi dimension and multi layer resolution by taking into account the Real World 5 Dimensions (Surface, Underwater, Air, Space, Cyber) and different layers & Resolutions Frame such as Fleets and Parties, Ships and Commercial Traffic, Crew & People Acceding Ports/Vessels, Services & Infrastructures. In addition it is necessary to consider critical issues such as (Bruzzone 2010):

- Non Conventional Operations
- Human Behaviors on (i.e. Crew, Stakeholders, Domestic Opinion)
- Services & Infrastructures
- Commercial Traffic & Yachting
- Port Infrastructures and Resources
- Joint Operations (i.e. Ship Inspections, Littoral Control, C5I2)

The authors have great experience in the use of Modeling and Simulation to reproduce complex maritime scenarios affected by asymmetric threats such as Piracy, Conventional Terrorism, CBRN (Chemical, Biological, Radiological and Nuclear) (Bruzzone et al. 2011, Bruzzone 2010). Threats and in the development of simulation models integrated by using HLA Standards (High Level Architecture), by taking into account all the previous mentioned aspects.

In particular this paper is focused on a solution including:

- **Cognitive Technologies** (i.e. Data Fusion, Human Behaviour Modelling, Intelligent Agents & CGF)
- **Modelling & Simulation** (i.e. interoperable Simulation, virtual environment, etc.)
- **Equipment & Devices** (i.e. Integrated Solutions)

The authors propose a federation of simulation models devoted to test and evaluate security procedures and to demonstrate M&S potential within marine asymmetric scenarios. In particular the research is inspired to a previous European R&D Project "GLOWS" where the authors were involved (Bruzzone 2005). GLOWS was devoted to identify needs and gaps in the following areas (Bruzzone et al. 2009):

- Biometrics Research: computational biomedicine, computer vision, computer graphics and deformable algorithm.
- Cyber Attacks of Transportation
- Wireless non human entities are being placed as elements of cyber space.

In similar way, GLOWS faces important points in freight handling, with special attention to Passenger and Container inspection procedures, currently requiring to be improved by introducing innovative technologies and new processes paying in attention security:

- Queuing models and inventory control analytical and simulation methodologies;
- Risk Factors for containerised cargo;
- Data mining and analysis on People and Material Flows. Bayesian methods;
- Standardised data submission;

In this research the authors propose a simulation framework based on the following previous experiences such as (Bocca et al. 2007; Bruzzone et al. 2004; Bruzzone 2007; Bruzzone et al. 2011):

- **IA-CGF & Human factors** for maritime security: models reproducing human factors and representing intelligent agents able to direct objects within interoperable simulators; these new *IA-CGF* (Intelligent Agents for Computer Generated Forces) modules are interoperable in HLA Federation (High Level architecture) and they include: IA-CGF Units (i.e. commercial ships, contractors on the ship, special teams, fisherman boats, coast guard units); IA-CGF HBL Human Behavior Libraries (i.e. fatigue, stress, aggressiveness, trustiness); IA-CGF NCF Non-Conventional Frameworks devoted to reproduce specific scenarios (i.e. piracy).
- ***PANOPEA:*** a simulation model based on intelligent Agents (IA) able to reproduce a complex framework related to piracy involving several thousands of vessels, plus all related activities (i.e. intelligence, ports, special forces, contractors, helicopters, UAV, etc.) (Bruzzone et al. 2011).

Figure 1. IA-CGF NCF and PANOPEA simulators

- ***PLACRA:*** simulator devoted to reproduce the crew activities and behavior on Oil Platforms as well as on vessels
- ***MESA:*** an integrated environment devoted to perform simulation and risk analysis in ports and maritime sector considering the evolution of emergencies (Bruzzone et al. 1999)
- ***FLODAF:*** tool devoted to support engineering and performance estimation of Data Fusion architectures and algorithms for analyzing the Data Fusion performances over complex Air-Naval scenarios including surface and underwater vessels, aircrafts.
- ***ST-VP:*** developed as a framework to support Training in marine environments; ST-VP includes all the different port equipment and even other marine devices and platforms

Figure 2. PLACRA, MESA, FLODAF and ST-VP Simulators

In the paper the authors propose a federation based on a synthetic environment and focusing on Safety and Security Training, Procedure Definition, Equipment Design and Virtual Prototyping.

3. SIMULATION MODEL AND POTENTIAL BENEFITS FOR PORT SECURITY

The authors propose a simulation framework to support the analysis and assessment of security procedures and plans within a port.

The framework includes:

- a synthetic environment reproducing the port facilities and components
- IA-CGF HBM to simulate the human factors affecting the activities of the vessels, boats, airplanes, coast infrastructures (i.e. crew behavior)
- IA driving the general traffic and critical entities (i.e. airplanes, yachts, ships, ground entities reacting dynamically to the Simulation Evolution)
- IA directing actions for the Port and Coast Protection
- IA directed Models reproducing Naval Resources, including platforms, weapons, individual sensors, ground infrastructures, C2 (Command and Control) and different information

The purpose is to develop innovative solutions, for port security improvement, able to:

- identify, analyze and reproduce "Intelligent Behaviors" by conservative and smart use of sensors, adopting behavior of general traffic, compromising info source, grouping and desegregating on the coast
- have Capabilities in Scenario Awareness
- have Capabilities in term of Autonomy
- have Capabilities in Coordinating different Agents

Considering, as example, the collision of two hijacked ships in a port, this scenario should include the following entities:

- The two ships (i.e. two cargo ships)
- Crew and Human Factors
- Other cargo ships, fishing ships and vessels driven by intelligent agents
- Coast Guard
- Port Authority
- Ambulance
- Local Police and government agencies
- Intelligence Agencies
- Sensors for threats detection
- Weapon Systems
- Threats
- External Traffic
- Logistics Infrastructures
- Litoral Resources

The federation architecture is proposed below:

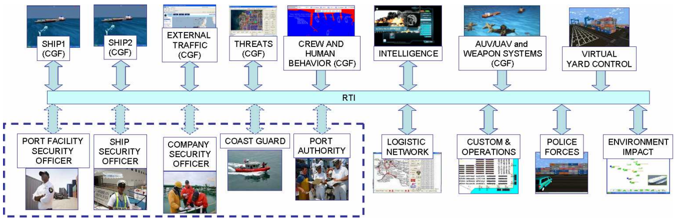

Figure 3. Federation Architecture

Particular attention is focused on the security responsible; these roles (mentioned in ISPS code) could be played by humans in order to define security plan and to act based on scenario evolution.
The proposed model is able to support both decision making and training. Due to interoperability features, this framework provides several benefits such as:
- Make more effective security procedures and plan
- Capability to discover or develop new security procedures
- Capability to quantify security procedures effectiveness in term of costs, time of threat detection, time of threat reduction or elimination
- Improve personnel coordination and communication
- Improve Personnel awareness and knowledge about security procedures

4. CONCLUSIONS

Harbour and Maritime Security is part of a wide Scenario and need to be addressed by an integrated approach. Marine Asymmetric Warfare is fast evolving introducing new issues and new threats affecting more and more subjects. Standards and Regulations exist but emerging technologies are key issues for investigating this domain respect new threats and supporting development of New Systems, Devices and Equipment but in particular personnel education. The research addresses the aspects mentioned above and proposes a simulation framework based on integrated approach and interoperability standards to support decision makers and trainees in applying security standards and procedures taking into account costs and security effectiveness. Existing solutions developed by authors could (coming also from industrial experiences (Bruzzone et al. 2011)be combined and integrated in order to create this simulation framework, allowing personnel training and port efficiency analysis.
It is evident that today simulation makes security issues opportunities to redesign logistics operations and infrastructures and facilities by testing new solutions and enabling technologies that are able to support this process.
In this context M&S provides quantitative support to decision makers for identifying solutions able to reduce the impact of the new threats with reasonable costs and without loosing operative efficiency.

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A SIMULATION-BASED APPROACH FOR RESOURCE MANAGEMENT AND CONTROL: A REAL CASE STUDY OF A SPANISH CONTAINER TERMINAL

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ABSTRACT
M&S has proved to be a day-to-day tool highly indispensable for complex systems design, management and training. Therefore, the proposed research study aims at developing a simulation model to recreate the complexity of the Algeciras port, one of the biggest container terminals in Spain. The simulation model is developed by using the discrete event simulation software Arena and is validated considering three validation scenarios. Lastly, based on the simulation outputs, a specific analysis about the port management and control policies has been presented.

Keywords: Container terminal, Simulation, Management, Scheduling.

1. INTRODUCTION

As attested by the International Maritime Organization, Container terminals (CTs) are important nodes in intermodal transport networks: sea-trade is more than 90% of the world trade and 80% of the general cargo is carried in containers. The containers trade growth along with the increased competitive pressure of the global market makes the need for optimized and effective container terminal operations evident (Ambrosino *et al* 2006). However, optimization, management and control of terminal operations are very complex tasks (Polo and Diaz, 2006). This complexity is inherent in the nature of terminal related processes and in the need to ensure high receptivity levels. In such a context, the capability of CTs resources and facilities to support different sizes of ships, the optimal dock design and the ability to improve decision-making are crucial aspects (Notteboom, 2007). Regarding ship size, important advances have been made and the load capacity of ships has increased considerably. In fact, to date, the capacity of the largest containerships in the world is up to 12,000 TEUs with lengths greater than 350 meters and service speed up to 25 knots allowing a travel time of 4 days between China and the U.S. west coast.

Moreover, the small vessels which make short trips cannot be neglected; this type of transportation is well known as Short Sea Shipping (SSS) and is supported by many governments and international institutions owing to the general will to reduce environmental impacts. Several research works dealing with SSS can be found in the literature; i.e. Paixao and Marlow (2002) present the main strengths and weaknesses of SSS whereas Martinez and Olivella, (2005) discuss specific opportunities for SSS. As mentioned above, to ensure high levels of receptivity and manage vessels of variable size optimally, an excellent dock design is required. To this purpose, Imai et al. (2005) define two dock design strategies: one is based on a discrete location with fixed points for berths while the other is based on a continuous location with no fixed points for berths. Since the continuous location strategy ensures higher flexibility and allows different kinds of ships to dock, the authors decided to adopt it in this research work. Therefore, based on this strategy, the dock is divided into segments and each incoming ship may take one or more segments depending on its length.

In addition, the literature review in the field of CTs management allows pointing out that simulation-based approaches have proved to be suitable for dealing with the main issues of CTs management and control: Liu et al (2002), Cortés et al. (2007), Longo (2007, 2010, 2011), Bruzzone (2002, 2004, 2010) and many others. Liu et al (2002) analyse the productivity of automated container terminals. Cotés et al (2007) and Arango et al. (2011) proposed a simulation model for analysing the freight traffic in the Seville inland port. Longo (2007, 2010 and 2011) propose some successful simulation models for container terminals management and analysis; in addition Longo (2010) presents an advanced simulation framework for investigating and analyzing the security problem within container terminals. Noticeably, in these works, simulation is used in combination with advanced methodologies like Design of Experiments or Response Surface Methods. Besides Bruzzone et al. (2010) describe distributed simulation architecture for marine workers training. Proven that Modelling and Simulation (M&S) based approaches are successful and useful tools in CTs decision processes, the purpose of this study is to develop a simulation model able to recreate the main operations (the loading and unloading of containers in the quay zone, the handling operations in the yard zone and the loading-unloading of containers to the land transports) of the Algeciras container terminal, one of the main ports in Spain and Southern Europe. To recreate the port complexity some simulation models have been developed and integrated by using the simulation software Arena. The rationale behind the use of a M&S based approach lies in the need for a real time operating tool which could be able to speed up and improve decision making processes. In addition the authors have a long experience in developing simulation models in Industry and Supply Chain nodes (i.e. Bruzzone et al. 2000; Bruzzone et al., 2007, Longo et al. 2012), with particular attention to mairne ports and container terminals (Bruzzone and Longo, 2012) for both decision making and training.

The work is organized as follows: in section 2 the real port scenario is presented; in section 3 the simulation model is described; in section 4 the main results are discussed; finally, conclusions are drawn.

2. THE REAL PORT SCENARIO

The scenario under study is a real system: the Algeciras container terminal shown in Figure 1.

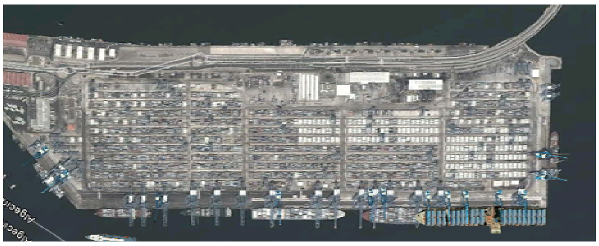

Figure 1 Layout of the Algeciras port

The container terminal is located on Juan Carlos I Quay, covers an area of 686,132 m^2 and has a capacity of 10,476 TEUs (20-foot containers). It has 1,941 m of berth with 14-16 m draughts. This container terminal is one of the APM Terminals and employs 15 portainer cranes (ten of them Post-Panamax, 3 x 70 tm, 3 x 65 tm, 4 x 50 tm, 5 x 40 tm) and 46 transtainers - RTG (19 x 61 tm, 19 x 40 tm, 8 x 32 tm). This information, along with all the data for the simulation model development, (resources, facilities and traffic data like arrival dates, departure dates, unload containers numbers, load containers numbers, etc.) have been taken from the annual report of the port authority of Algeciras 2010. Table 1 shows an abstract on freight traffic (159 ships came to the port in October). The 159 containerships transported 214.065 TEUS (20-foot Equivalent Unit) and 88.7% of this freight traffic was transit traffic toward other ports; therefore the Algeciras terminal container is considered a hub container terminal.

In addition, onsite inspections and interviews of the top management were executed with the aim to gain knowledge about the system under study. As result of these preliminary research activities, a conceptual model of the main container terminal operations was outlined. The conceptual model draws up the main processes, objects, entities and actors that have a crucial influence on the system performances and therefore have to be included within the simulation model. On the other hand all the elements that were considered outside the scope of the study have not been included. Therefore the conceptual model is representation of the system under study and it is based on the following assumptions:

Table 2 Freight traffic

Traffic	Total 2010	October 2010	Represent
Total TEUS	2,810,242	214,065	7.62%
Transit TEUS	2,493,872	195,852	7.85%
Import TEUS	81,323	8,829	10.86%
Export TEUS	86,439	9,384	10.86%
Containerships	2,308	159	6.89%

- The dock is divided into 82 segments of 24 metres each.
- Three types of ships are considered: small vessels, whose length does not exceed 8 segments; medium-size ships with a length between 8 and 14 segments; large ships with a length between 15 and 17 segments.
- As quay cranes move on the same railway, possible interferences between displacements should be considered.
- Only 40 feet standards containers size are considered.
- The maximum number of working sections per ship is three.
- The staking plan is known.
- The minimum distance between two ships involved in loading/unloading operations is one free segment.

Based on this assumption a simulation model has been developed and used to decide which block of the storage area has to be used for containers unloading. The precise containers location (micro-simulation) will not be considered in this work.

3. THE SIMULATION MODEL

The simulation model of the container terminal recreates the main operations of the container terminal: the container pre-marshalling problem, the landside transport, the stowage planning problem, the yard allocation problem, etc. See Steenken et al. (2004), and Stahlbock and Voß (2008) for complete and interesting reviews on the most relevant problems in a container terminal. To this purpose, the simulation model can be profitably used to evaluate the effects of alternative decisions-making policies without affecting the behaviour and the performances of the real system.

The simulation model has been developed by using ARENA, a commercial discrete event simulation software which has been chosen for its recognized capabilities in complex systems modeling and simulation and also because it can be easily integrated with other software/tools for input data and simulation results analysis (moreover, it includes Visual Basic for further applications development). It also supports importing Microsoft Visio flowcharts and reading from or outputting to Excel spreadsheets and Access databases.

The simulation model proposed in this research study can be considered the first step toward the development of a support tool for the Algeciras container terminal management. The above mentioned tool will be based on the combined use of both simulation and optimization approaches: simulation will be used for optimization model testing in different situations (scenarios). However, in this preliminary work the focus is on the simulation model development therefore scheduling and resources assignment decisions are taken by using basics rules (management modules). These rules will be later replaced with an optimization model. The conceptual framework where the simulation model is placed is shown in Figure 2. This figure underlines that the main input to the simulation model are: the real data (starting module) and the rules that are currently followed to implement the CT management processes (Management Module). The Starting, Management and Simulation modules are described below.

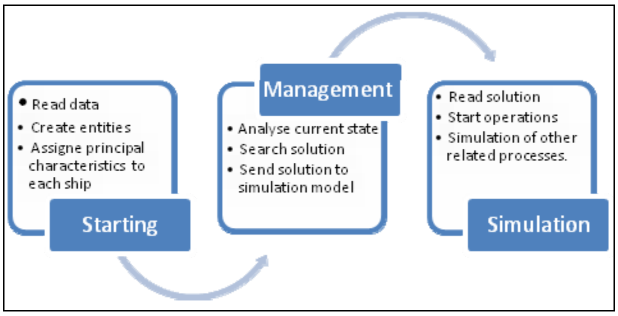

Figure 3: Models interaction

3.1. The Starting Module

Real data (i.e. arrival times, ships names, shipping companies, etc.) are taken from an external file. For testing purposes in the current version of the simulation model, these data have been extracted from the Algeciras port real database and refer to October 2010. These data have been mainly used to schedule ships arrivals; to this end a set of modules for data management and manipulation has been introduced (Figure 3). Among them, the ReadWrite module is the most important: it reads or writes values in an external document type txt, dat, xls, etc. After reading the external file, the entity representing container ship is created. The ship entities are characterized and identified by a set of attributes, including among others: the scheduled arrival times, the ship name, the shipping company, the length of the ship, the number of sections with containers, the number of containers to be loaded and unloaded, the locations of these containers in the storage area, etc.

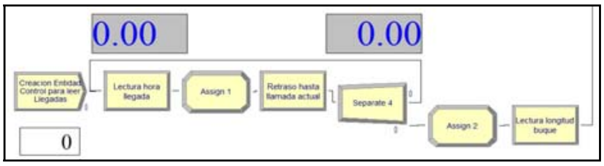

Figure 4 Read data modules

3.2. Management module

When a ship is created (arriving at the CT), it is sent to a scheduling module, where basics rules are applied to solve the quay crane scheduling problem and the berth allocation problem. These modules are shown in figure 4. Currently such rules are implemented based on suggestions/experience of the planners working in the real system.

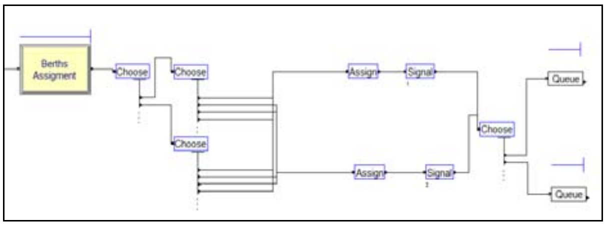

Figure 4: Scheduling modules

3.3. Simulation module: virtual dock and complementary operations

Each ship has an attribute that allows identifying the segments that have been assigned to that particular ship. In the simulation model a virtual dock has been developed, it is used to take and represent the segments that each ship will need. Therefore, the virtual dock moves along the dock line representing the specific group of segments where the operations are being carried out and allows the unloading, loading and transportation processes of all the containers to be simulated. The modules of the virtual dock are shown in figure 5.

Basically, the ship berths in the virtual dock until it has completed the handling operations. After completing the handling operations, the ship is ready to leave the dock and get into the towing process releasing all the resources that had been assigned to (i.e. the dock segments, the quay crane and the virtual dock). Distances between the points of the storage area and each location (segment) of the dock line are stored in a matrix.

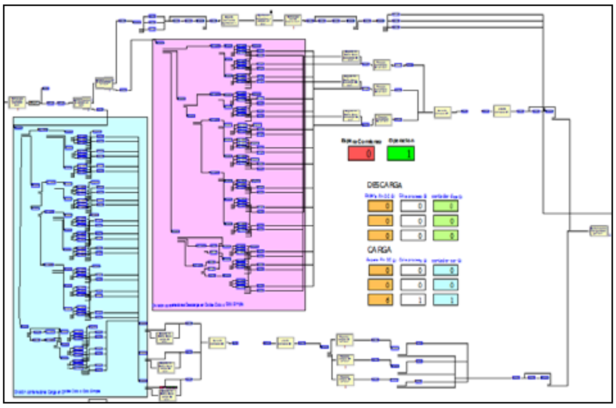

Figure 5 Virtual dock modules

Moreover, the virtual dock simulates resources assignment based on the rules of the management module, i.e. the quay crane scheduling. In fact, according to the assumptions introduced in section 2 , a ship could have from 1 to 3 work sections (with containers), and therefore 1, 2 or 3 quay cranes could be assigned to each ship. Additional examples of ships operations are depicted in Figure 6: the firs ship has 3 working sections and 1 quay cranes assigned, the second ship has 3 working sections and 2 quay cranes assigned and the third ship has 2 working sections and 2 quay cranes assigned.


Figure 6 Ships in operations

Moreover, in order to recreate the CT operating conditions, complementary operations have been included in the simulation model. As a matter of fact, when ship handling operations occur, landside handling operations, which involve shuttle vehicles like forklifts and trucks, have to be performed accordingly. Therefore, on the simulation side specific modules for complementary operations are needed for ensuring a logical flow of containers import and export. Note that the operations time depends on the containers location.
Figure 7 and Figure 8 show the truck modules and the train modules respectively. These modules have been developed as a part of the simulation model to take into account landside operations.

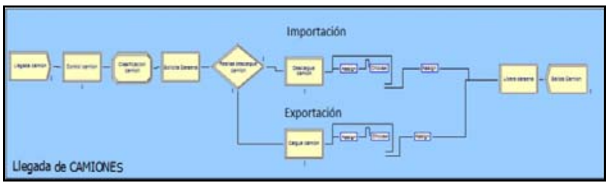

Figure 7: Truck modules

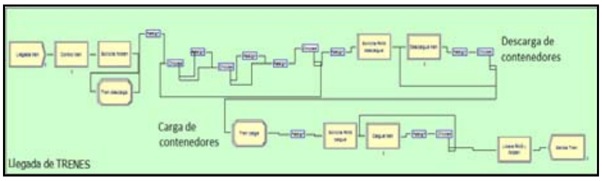

Figure 8: Train modules

Lastly, the animation of the simulation model is shown in Figure 9 where the most important areas are depicted: A identifies the trains area, B identifies the trucks area, C identifies the storage area and D is the ships operation area.

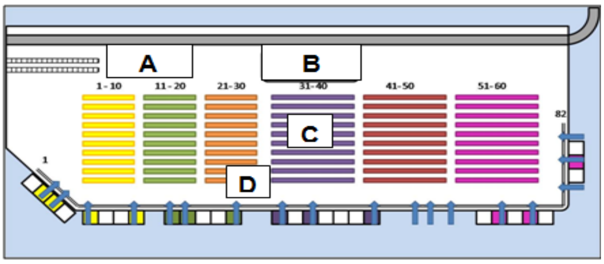

Figure 9: Animation of the simulation model

4. RESULTS AND ANALYSIS

Even if the main goal of the first part of this research work was the definition of the CT conceptual model and the implementation of the simulation model, some preliminary analyses have been carried out to validate the simulation model. Specifically three different scenarios have been considered. The initial scenario is based on the real data taken from the annual report of the Algeciras port authority. These data include arrival times and ships information for 159 containerships. The remaining information such as the number of work sections and containers to load and unload were calculated according to the real freight traffic (107.032 40 feet standard containers). The simulation results for this first scenario show the capability of the simulation model to come up with acceptable results in terms of waiting time, handling time and service time.

Apart from the first scenario, two additional scenarios have been considered in order to check the capabilities of the simulation model to behave correctly in case of increases in containerships traffic and containers traffic. In fact, for the second scenario, the ship arrivals times are the same of the first scenario while the number of containers carried by each ship was increased by 20% (128,438 40 feet standard containers in total). For the third scenario, the number of containers and sections per ship are the same of the second scenario while the number of ship arrivals was increased by 20 units (179 containerships and 128,438 40 feet standard containers in total), it means the 12.5% raise in containership traffic and the 20% raise in containers traffic. In this last case in order to assign correctly the ships arrival times a distribution fitting procedure on the real data has been carried out (see Montgomery and Runger, 2006 for further information about distribution fitting procedures). The vessels arrival times were assigned according to the results of distribution fitting procedure (Poisson process, exponential distribution) and the same approach was adopted for ships length assignment.

For each scenario, ten model replications were executed therefore thirty replications were analysed. Simulation results and analysis are reported in the remaining part of this section.

Table 2 summarises ships operations times expressed in hours; handling operations time, resources waiting time and logistic operations time were considered. The sum of these time values is known as service time and is an important data for evaluating CT performances. Since containers traffic and ships traffic are different for each scenario, the results in terms of service time are also different. However, the minimum handling time has similar values because the probability that a ship with few containers to load/unload will arrive, is the same for all the scenarios. Furthermore, the second scenario has the worst results compared to the other scenarios. This is consistent with expectations because the container traffic was increased. Therefore, from this preliminary analysis, it is possible to ascertain that the simulation model behaves coherently.

		Scenario 1	Scenario 2	Scenario 3
Waiting time	**Min**	0	0	0
	Max	4.15	7.91	4.05
	Average	0.25	0.31	0.25
handling time	**Min**	4.96	4.99	4.69
	Max	15.96	19.24	15.8
	Average	6.85	7.65	6.72
Service time	**Min**	4.96	4.99	4.69
	Max	16.16	20.43	16.33
	Average	7.1	7.98	6.97

Table 2 Ships operations time (h)

Figure 10 shows the ship rate for each interval of the handling operations time (lower than six hours, between six and seven hours, between seven and eight hours, between eight and nine hours, greater than nine hours). Even in this case, since the number of containers for each ship is greater in the second scenario, the first and the third scenario have the best results in terms of handling operation time which is between 6 and 7 hours for almost 80% of the containerships.

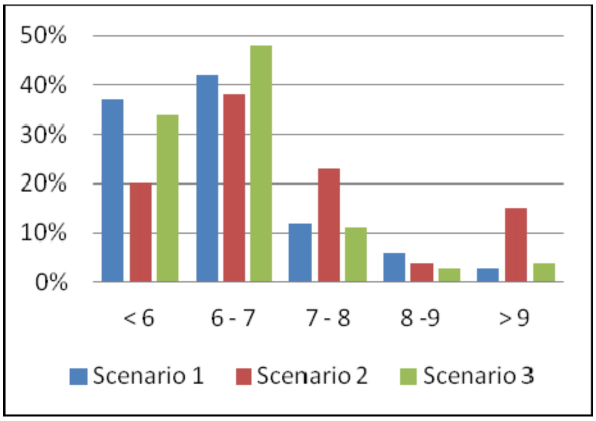

Figure 10: Handling operation time

Analyzing the workload for each segment berth (see Figure 11), it is possible to notice that certain sections have a greater workload than others. It happens because the sections close to the streets and to the dock are preferred to the other sections since they allow minimizing the total handling operation time. Once again the analysis of these preliminary results allows pointing out that the simulation results are coherent with the expected results and with the real system behaviour.

At this stage, the simulation model is used to carry out further analysis on the system behaviour. In detail, simulation runs have been executed in order to identify the criticalities and gain a greater insight into the CT management and control.

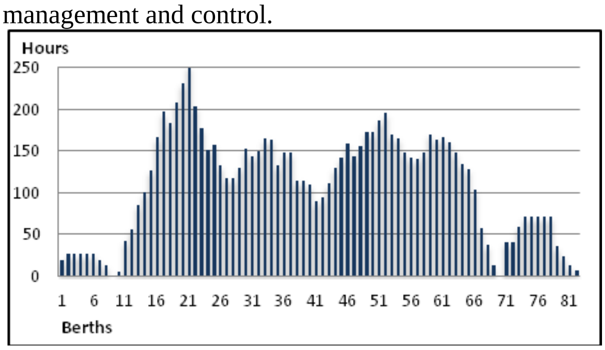

Figure 11: Berth segments workload

To this purpose, the main causes of waiting time were studied. As reported in Figure 12, the main bottleneck in the Algeciras container terminal is the berth and its bottleneck effect increases when the traffic increases. Lastly, the bottleneck called “Others” represents other resources less important for this study such as; Tugboats, Trucks, Forklifts, etc.

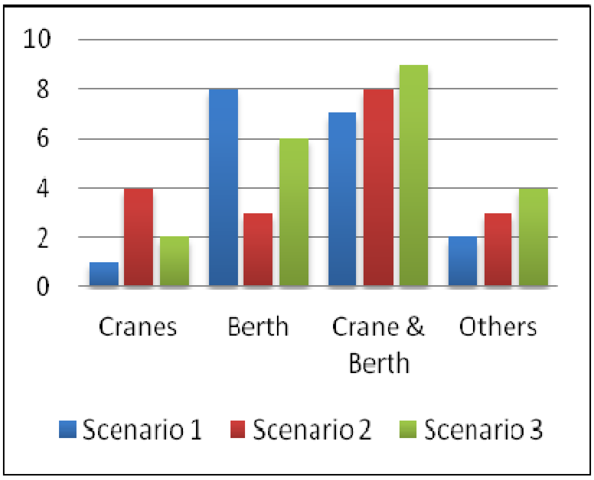

Figure 12: Mains bottlenecks

The Quay cranes workload has been analyzed also, in fact it is very important to schedule this resource properly for maintenance activities. Figure 13 shows the containers handled for each crane and it is possible to notice that cranes number 1 and 2 have the lowest workload owing to their localization in the initial dock line.

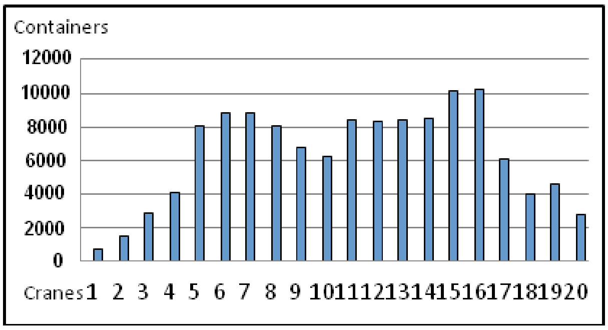

Figure 13: Quay cranes workload

5. CONCLUSIONS

In this paper a well-established hub port has been considered: the Algeciras port. The port operations have been modelled by using the discrete event simulation software Arena and three scenarios were considered for validation purposes. First, the real freight traffic was considered; then the second scenario was developed considering a containers traffic increase; lastly in the third scenario a ship arrivals increase was considered.

The output data analysis allows pointing out that simulation is a valuable tool with great potential for CTs management and control. In addition, the simulation study output suggests that berths resources are the main cause of bottlenecks, therefore to serve the new freight traffic current berths resources have to be improved. As already mentioned, future work will involve the development of an optimization module that will be integrated within the simulation module in order to optimize management policies for the Algeciras port. Furthermore, handling equipment such as forklifts and Reachstackers, will be considered more accurately for minimizing costs, handling operations times, bottlenecks, etc.

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MARINE PORTS ENVIRONMENTAL SUSTAINABILITY: A STATE OF THE ART OVERVIEW

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ABSTRACT
In recent years sustainable development has become a problem of primary importance. This article focuses on the currently marine ports situation, offering a perspective through some relevant research works, from the past until today. In the second part of the paper a simulation based-tool for measuring the environmental impacts in marine ports area is briefly presented. The simulator is able to consider the impact of the main factors affecting the sustainability of port processes and operations such as CO_2 emission, ship air emissions, air quality, ship discharge, etc.

Keywords: marine port sustainability, emissions, sustainable development, M&S-based approaches

1. INTRODUCTION

Heightened sensitivity of social communities along with environmental protection laws (enacted in many Countries and mainly from the European Community), have made sustainability a key factor in many application fields.

The most common and recognized definition of sustainability can be found in the Brundtland report : “meet the needs of the present without compromising the ability of future generations to meet their own needs” (OCI, 1987). Therefore sustainability implies the capability of setting up growth processes avoiding either overexploitation of resources or damages for future generations. As a consequence, resources preservation and efficiency are basic requirements to achieve sustainability and in this perspective technical, social and environmental aspects have to be considered simultaneously.

In its historical perspective, sustainability can be dated back to the 1970s when the oil crisis propelled the first studies on natural resources depletion. In 1972, the report “Limits of Development" (Meadows et al.,1972), stated that productivity growth would have exhausted all the natural resources in a few decades. In the same year the United Nations Conference on the Human Environment, which was held in Stockholm, laid down the foundations for the strategic path toward sustainable development. Thereafter market pressures and regulations have drawn business attention to environmental issues: customers and suppliers are increasingly demanding minimal negative impact on the natural environment (Karakosta et al., 2009, Golusin et al., 2011). As a result the so-called ‘green management’, has emerged as a key factor for firms, see Shrivastava, (1995), Klassen and Whybark, (1999), Lun, (2011), and many others. In this scenario waste elimination, recycling, waste treatment and final disposal are crucial aspects (Crittenden and Koloczkowski, 1995); in particular energy consumption and wastes can be very high in manufacturing industries therefore proactive tools to investigate current and alternative practices are required. On this purpose Mani et al. (2011) propose an approach based on Discrete Event Simulation (DES) and Life Cycle Assessment (LCA) to tackle sustainability issues in manufacturing industries. Similarly Lee at al. (2012) suggest a simulation-based prototype for sustainability analysis of manufacturing system. Moreover a three-dimensional approach for sustainable production, which considers technology, energy and materials, was proposed in Yuan et al. (2012).

The “triple bottom line” approach has emerged as a tool to measure corporate performances including environmental and social dimensions (Elkington and Trisoglio, 1996). Based on this approach Azapagic and Perdan, (2000) propose a general framework with a comprehensive set of indicators for assessing the level of sustainability in industry and identifying more sustainable options for the future. Moreover the need for assessing and evaluating sustainability interested many authors, to name a few Labuschagne et al.(2003); Gasparatos et al.(2007), Lee and Saen (2011), Basurko and Meshabi (2012), Joung et al. (2012), etc. However, environmental impacts affect all the stages of products/services lifecycle therefore sustainability has to be considered along the entire supply chain, starting from row material procurement up to products disposal.

The extension of the traditional supply chain to include activities taking into account environmental impacts, brought out the concept of “Green supply chain (Beamon, 1999). Needless to say that the sustainability of the chain depends on the sustainability of every firm of which it is made up (Hart, 1995). For this reason Neto et al. (2007) proposed a multi-objective programming (MOP) approach to support sustainable design in logistics networks. Furthermore in the last few years the current sustainable approaches were extended to the inventory management (Nikolopoulou and Ierapetritou, 2012).

The state of the art analysis allows pointing out that sustainability cannot be neglected; it is an imperative both in logistics and industry.

Moreover, considering that marine ports are important nodes in intermodal transport networks (note that sea-trade is more than 90% of the world trade), this research work aims at facing the issue of sustainability in seaports.

This paper examines the environmental situation in marine ports relating to sustainability issues. It identifies four main areas of interest. In the section 3 the most common air pollutants are considered and discussed. In the section 4 the paper provides an overview of the port operations impact on water quality and energy consumption. In the section 5 M&S is proposed as a powerful and successful approach to evaluate sustainability in ports. In the section 6 a brief description of sustainable technologies in the port area is provided. Finally the paper briefly presents a simulation based solution developed by authors to evaluate port processes and operations sustainability.

2. ENVIRONMENTAL SUSTAINABILITY IN PORTS

Market and governmental pressures make sustainable development a critical issue in ports management and control. Considering some aspects like greenhouse gas emissions and energy consumption it is evident that the environmental impact of port activities cannot be neglected. To this end "Agenda 21" is recognized as the first initiative toward environmental efficiency within harbours: the concept of "Greenport" has been introduced and since then the quest for environmental friendly measures and technologies being able to minimize wastes, has never stopped (Langeweg, 1998).

As matter of fact, a great deal of effort has been made to improve energy efficiency, renewable sources exploitation and storm water collection and reuse. Moreover to cope with sustainability issues, the main areas of interest have been detected and classified as follows:

- Air quality: it includes the quest and development of less polluting equipments for cargo handling and the use of alternative fuels for vehicles.
- Climate change: it includes the intervention aiming at reducing some chemical agents that are responsible for the climate change.
- Water quality: to deal with this problem more stringent discharge limits on storm water runoff were introduced.
- Energy conservation & Renewable energies: many port areas are inquiring about the possibility of buying green or renewable energy.

Therefore the main actions toward sustainability can be ascribed to the areas above mentioned. As stated before this research work is intended to analyze the eco-friendly initiatives within marine ports and to propose a simulation-based approach in order to foster environmentally acceptable operational and management processes. To achieve these research goals the main issues related to sustainability in seaport areas have been considered and analyzed. As a result a state-of-art overview is proposed in the sequel (section 3 and 5).

3. CLIMATE CHANGE AND AIR POLLUTION: A CHECK ABOUT EMISSIONS

Greenhouse gas emissions contribute both to climate change and air pollution, for this reason it is important to quantify and monitor emission levels. In addition, considering that ports are vital nodes of transport infrastructures, it is worth assessing the typology and the quantities of emissions that are released into the atmosphere as a result of port processes (Howitt et al. , 2011). To this end, several studies on different worldwide ports have been carried out, i.e. Gupta et al. (2002), Saxe and Larsen (2004), Lucialli et al. (2007), Joseph et al. (2009), Villalba and Gemechu (2011), and many others. From these studies it is possible to notice that the most common air pollutants include diesel exhaust, particulate matter (PM), volatile organic compounds (VOCs), nitrogen oxides (NOx), ozone, sulfur oxides (SOx), carbon monoxide (CO), carbon dioxide (CO_2) formaldehyde, heavy metals, dioxins, and pesticides (often used to disinfect products). Among them, CO2 can be recognized as the main responsible for global warming, therefore there is a great deal of works that propose emission-based models for assessing CO2 emissions within marine terminals, i.e. Berechman and Tseng (2012), Geerlings and Duin (2011), Voet (2008), and many others. However, to estimate emissions and set up management policies against air pollution the main pollutant sources have to be identified; these sources include marine vessels, trucks, locomotives, and off-road equipment used for moving cargo (Bailey and Solomon, 2004). Air pollutants and pollution sources are capital aspects to control and minimize the emissions whose effects can lead to far-reaching consequences on air quality affecting large geographical areas (Streets et al., 2000). In literature emissions have been divided into two main classes: sea-based and land-based emissions. The former are related to ships arrivals, departures, hoteling and manoeuvring whereas the latter depend on port activities and include electricity consumption, fuel, heating and generation of waste (Villalba and Gemechub, 2011).

Although sea-based emissions make up a small percentage of the overall ship emissions (Whall et al., 2002, Dalsoren et al., 2009), in-port traffics are growing noticeably therefore the overall ports workload keeps growing and as a consequence emissions of NOx, PM and SOx cannot be ignored. To this purpose some assessment methodologies can be found in Trozzi (1996), ENTEC (2002), Gupta et al. (2002) , Peng et al. (2005), Tzannatos (2010), Villalba and Gemechu (2011), and many others.

In addition, emission control effectiveness is related to the ability to develop detailed and accurate emission inventories for ports (Gupta et al., 2002; Joseph et al., 2009). Current methodologies and best practices for preparing port emission inventories were proposed by the US EPA (Iovanna and Griffiths, 2006).

Many city seaports have done emission inventories to name a few: Los Angeles, Rotterdam, Oslo, and New York, (Den Boer and Verbraak, 2010). In addition De Meyer et al. (2008) estimates the atmospheric emissions by international merchant shipping in the four Belgian seaports: Antwerp, Ghent, Ostend and Zeebrugge.

The impact of such emissions on air quality and environmental health is significant, as many research studies on this matter are have shown: Isakson et al (2001), Saxe and Larsen, (2004), Gariazzo et al., (2007), Lucialli et al., (2007), Lonati et al. (2010) and many others. Moreover Peris-Mora et al. (2005) propose a system of environmental indicators for the analysis of environmental impacts whereas Hartman and Hartman and Clott (2012) developed a model in order to control costs and emissions of the trucks within ports.

All these works allow pointing out the need for enforcing strict measures in order to curb environmental damages. The approaches that can be undertaken may rely on low-cost initiatives or more significant investments, for instance restrictions on truck idling, use of low-sulfur diesel fuels, shore-side power for docked ships, alternative fuels, etc.

4. WATER QUALITY AND ENERGY CONSUMPTION

Besides air quality and climate change, water quality and energy consumption are two key issues related to sustainable management of ports. Ports operations, in fact, impact on water quality and require high energy consumption.

Water quality may be affected from waste discharged by marine vessels, oil spills, dredging, etc. In addition contaminants and sediments can be disseminated by the tides therefore marine zones adjacent to harbours could be polluted by the waters coming from the harbours (Hart et al, 1986; Cornelissen et al., 2008). In this context, researching and developing tools to enable an efficient environmental management of harbour waters is particularly interesting for scientists and engineers (Grifoll et al, 2010). As a matter of fact, starting from Cotter (1985) that proposed a statistical method for surveying water quality, many research works have been published, i.e. Ondiviela et al. (2012) developed a methodological standard to provide port authorities with procedures for investigating the influence of port activities on the quality of water bodies. Valuable contributions can be found also in Kantardgi et al. (1995), Fabiano et al., 2002, Ronza et al., 2006, Eide et al., 2007, Palani et a. (2008), Ross and Shrestha (2008), Neacsu et al. (2009), De La Lanza et. al (2010), Wu et al (2010), Giurco and et al. (2011) and many others.

Energy consumption is another key aspect in dealing with sustainability. International seaports are striving to address energy challenges like save energy and maximize energy efficiency. To this end, Port Authorities are committed to support a more efficient and effective energy management in different ways, namely by using renewable energy sources (i.e. sun, wind, etc), installing biodiesel or biofuel systems and assessing available technologies. These initiatives drew the attentions of many researchers that have sought to develop new approaches for assessing energy requirements, monitoring energy consumptions, detecting new solutions for energy saving and new techniques for the exploitation of renewable energy sources with a lower environmental impact. To name a few: Birol et al. (1997), Todd (1997), Jesuleyea et al. (2007), Mohamed and Lee (2006), Kadiri et al. (2012) and many others.

5. MODELING AND SIMULATION-BASED APPROACHES FOR SUSTAINABILITY

To achieve sustainability all the aspects analyzed in the previous sections should be considered simultaneously. Therefore it is evident that in sustainability analysis many factors, which interact each other, have to be considered. The nonlinear nature of this kind of systems highlights its intrinsic and high complexity and consequently the need for integrating tools able to handle sustainability goals. To this end, M&S has proved to be a powerful and successful approach to cope with complex systems analysis and management.

In fact, M&S allows recreating and analyzing the operational processes taking place within marine ports in terms of their environmental impacts. However, past related works analysis show that M&S applications for sustainability are still limited to specific aspects whereas comprehensive and integrated tools, providing global impacts evaluations coupled with economical analyzes, are still missing. In other words, many attempts have been done to investigate (through simulation) specific sustainability-related issues but a comprehensive model where all this issues and their interactions are simultaneously considered, is not available currently. Some of the most representative works on M&S applied to sustainability are summarized in the remaining part of this section.

Johnson et al. (2006) worked out a simulation model to evaluate energy consumption and emissions in a terminal. Saxe and Larsen proposed a meteorological simulation model to assess the urban dispersion of air pollutants in three Danish ports. Roso (2007) presented a simulation-based approach to examine the dry port concept and the emission levels. Kim et al. analyzed the influence of ship emissions on ozone concentrations in a coastal area, by using two simulation scenarios.

Therefore these works on M&S aim to point out the effects of the major pollutants evaluate alternative and environmental-friendly strategies and solutions (Molders et al., 2010).

Analyzing in detail the simulation studies above mentioned it is possible to ascertain that the main modeled elements are:

- Port waste: garbage, sludge and waste materials resulting from industrial and commercial operations.
- Noise pollution: loading and unloading operations and movement of ships in water influence the local sound.
- Emissions to air: CO_2, NO_x, CO, SO_2 and PM_{10} are the major.
- Hazardous cargo: in reference to the transport of potentially flammable, corrosive, reactive or toxic materials.

Moreover in many simulation models meteorological conditions are a key input since they influence pollutants concentrations in the air. In fact the wind is responsible for pollutants transport and dispersion whereas the intensity of solar radiations affects kinetic and thermodynamic conditions of reactions and lastly water distribution is responsible for sediments deposit (Marmer and Langmann, 2005). In addition, in a simulation study on ports sustainability, physical and chemical conditions of the environment have to be modelled carefully. In fact, for instance, it has been shown that sulphate aerosols decrease as altitude increases whereas NO_x decreases when pressure drops.

6. SUSTAINABLE TECHNOLOGIES IN THE PORT AREA

As mentioned above, environmental sustainability in seaports is a very important issue given the rapid increase of ship traffic. For this reason, sustainability agendas are challenging port authorities that are required to use cleaner technologies and port assets more efficiently (Daamen and Vries, 2012). A brief description of the main environmental-friendly initiatives currently available is provided below.

6.1 Cold-ironing

When ships are berthed, they rely on onboard diesel auxiliary engines to power the equipments needed during loading and unloading operations, i.e. lights, ventilation and pump systems, cranes, etc. However, these auxiliary engines (that usually use low quality fuels) emit significant quantities of pollutants and green house gases (Hall, 2008). In this framework, cold-ironing (also known as Alternative Maritime Power (AMP)) can be seen as an alternative to onboard power generation systems. Renewable energy sources or onshore power systems can be used to power ships equipments during the port operational processes. In this way, emissions can be substantially reduced; in fact it has been proved that a 20 MW AMP can lead to a 52.7% reduction of CO_2 emissions and a 39.4% reduction of PM

6.2 Electrical vehicles

Nowadays innovation is leading to more sustainable applications also in the automotive industry. In fact replacing traditional engines with electrical vehicles allows reducing emission and saving energy (40% energy saving).

6.3 Liquefied Natural Gas (LNG)

Typical LNG fuels are methane and ethane. It has been proved that LNG allows a 20% reduction of carbon dioxide emissions and also a reduction of sulphur emissions.

6.4 Onsite energy production from renewable sources

Photovoltaic systems can be used to power both port equipments and ship equipments. Currently photovoltaic panels are being installed also on roofs of cruise ships.

Seaport areas are generally exposed to the wind (Solari et al., 2012) therefore are considered suitable sites for wind turbines installation.

Furthermore, biomass is gaining an increasingly importance as source of energy, in fact it offers the possibility to reduce greenhouse gas emissions by 20%, in line with the target imposed by Kyoto Protocol. (Heinimo and Junginger, 2009). For this reason biomass power station installations are increasing within port areas.

7. CASE STUDY

After having considered the issues related to sustainability in seaports, the attention has been focused on the development of a simulation-based tool to be used for the evaluation of the sustainability of marine ports processes and operations. To this end, the GreenLog simulator (Green Logistics simulator) was the starting point of this research work (Bruzzone et al. 2009-a; Bruzzone et al. 2009-b). Actually the authors have a remarkable experience in developing advanced simulation models in Supply Chains and Industry (see for instance Bruzzone et al. 2000; Bruzzone, 2002; Bruzzone, 2004; Bruzzone et al., 2007; Longo et al. 2012).

GreenLog is part of the “Italian Green Logistics Initiative” that involved Industry, Academy and Governmental Institutions. In detail, GreenLog is a Web Based Simulator implemented by using Java™ technology. It has been developed in order to provide a decisions support tool for measuring the environmental impacts of supply chain nodes considering factors such as: air emissions, waste disposals (i.e. rubber due to tire trucks consumption) terrain degradation, noise, spills, dusts etc.

In particular for the Port Impacts environmental Model development, several factors have been considered:

- Garbage & Port Waste;
- Dredging;
- Dust;
- Noise;
- Ship Air Emissions;
- Air Quality;
- Hazardous cargo;
- Bunkering;
- Ship Discharge.

In addition, it is important to note that when environmental impacts are evaluated often, just the impacts related to the “on going” state are taken into consideration; sometime this is a wrong approach because it is necessary to consider the whole port life cycle to avoid mistakes. In fact, all the activities required to build and set up all the port facilities have non negligible environmental impacts. In other words, the EI model has been developed in order to include the environmental impacts of all the activities that have been carried when the port was built (i.e., emissions, fuel consumption, pollutants released to the environment, waste, etc). Moreover a correct assessment of these impacts binds to spread them out over the entire port life-cycle. Needless to say that this approach results in a more precise estimate of the environmental cost of port processes and operations.

7.1 The GreeLog Simulator

The authors developed an object oriented simulators for analyzing complex supply chain nodes scenarios in term of overall efficiency and sustainability (Arnold 2006). This simulator it is named GreenLog (Green Logistics simulator) and it is based on web technologies for guaranteeing easy access and distributed use. In fact GreenLog is part of a project for supporting environmental impact mitigation in Italian Logistics; this initiative involve Agencies (i.e. Assologistica Cultura e Formazione), Networks (i.e. Simulation Team), Institutions (i.e. MITIM-DIME Genoa University) and Companies (i.e. Campari, CRAI, MARS, Sony, etc.); Green Logistics initiative (Gifford 1997) it is lead by MISS DIPTEM from technical point of view and it is based on a web portal (http://st.itim.unige.it/greenlogistics) where it is possible to access to several services:

- Company Qualitative and Quantitative Questionnaire
- Self Measure of the Company Logistics Green Level based on automated configuration of the specific simulation model
- Supply Chain Simulation for measuring impacts and performances.

The model is based on the following main objects devoted to reproduce infrastructures, processes and performances; among the others it is possible to list the following objects:

- Logistics Nodes
- Logistics Link
- Vectors
- Logistics Flows
- Environmental Impact

The most interesting part is that the Green Log simulator can be used for both building the simulation model of an entire supply chain (the standard configuration of the software is a three echelon supply chain) and the simulation model of a specific logistic node (such as a marine port). In this last case all the objects provided within the software can be used to model the main port operations and processes, such as vessels arrivals, vessels entrance in the port area (supported by tugboats), vessels docking operations, loading and unloading operations, vessels departure, etc. The main idea is to recreate - by using the objects provided by the software - the complexity of the marine port scenarios and to consider all the factors (i.e. CO2 emissions, garbage and port waste, oil and fuel leakages, noise, etc.) that may have a significant impact on the sustainability of the port operations. To this end the green log simulator is able to evaluate the environmental impact (EI); EI can be attributed to each of the object included in the simulation model (i.e. vectors such as straddle carriers or tugboats, logistic flows such as container movements, etc.) and corresponds to emissions, disposals, consumption etc. In fact each EI is related to a specific variable connected with the object responsible of the environmental impact and therefore it is possible to module the EI based on the dynamic evolution of the simulation and based on relations that may involve different other variables such as constants, distances, times, flow volumes, flow masses, costs, flow types, etc.

Due to the user nature, the authors designed GreenLog in order to allow graphical construction of the simulation model as proposed in figure 1.

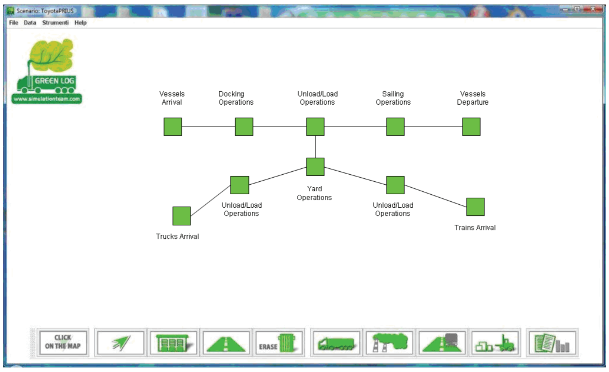

Figure 1: Green Log simulator GUI

The simulator provides easy GUI for all object creation and configuration as well as automated reporting capabilities in figures; another important feature it is the capability to present the results graphically issues directly over the logical network in order to identify critical component.

The nature of the environmental phenomena and the uncertainty on major aspects may strongly affect the reliability of the results: i.e. comparing environmental impact of different compound emissions and estimation of their social costs. Due to these reasons it is critical to proceed since the beginning in Verification, Validation process with extensive test; even if the green log simulator has been extensively verified and validated, this has been done specifically for supply chain scenarios. In this case the GreenLog simulator has been opportunely customized to be used also within the marine ports area, therefore this still requires an additional verification and validation effort that will be carried out as future research activities.

8. CONCLUSIONS

This paper proposes a survey of the state of the art on the sustainability of marine ports processes and operations. The article clearly highlights that sustainable design and development have become critical issues for major marine ports (this is particularly true when the marine port is located within an urban context, as the case of some major Italian and European ports). In the second part of the paper, the authors present the customization of the Green Log simulator and how it can be used within the marine ports area. The Green Log simulator is able to recreate the main processes and operations that usually take place within the port area and measuring the environmental impact associated to each operation. Further research activities are still ongoing in terms of verification and validation of the Green Log simulator when applied to marine ports operations.

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