THE GENERIC ANIMATION AND SIMULATION TOOL FOR PORTS AND TERMINALS

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Abstract: Simulation is one of the most attainable decision making techniques of modern times. It is used to support important policies and decisions. This paper presents the development of a simulation application called 'Port Process Simulator' or ***PPS***. It has recently been installed and is working in three ports in the Baltic States. The focus of this paper is the architecture, simulation technique, the animation model and the approach applied in the development of the simulator. The paper also demonstrates the usefulness and the application of the PPS to the end-user.

Keywords: Simulation, ports, stochastic behaviour, discrete event, process-oriented, business model, architectural design, animation, concern-net, relational database.

1. INTRODUCTION

Sea Ports plays a vital role in the development and progress of any region. Sea transportation is one of the most critical components in global and European freight transport logistic operations. The Common Transport Policy of the European Commission highlights the enormous need of taking the 'load off the roads' and replacing it with sea and rail transport. The success of business, industry and the economics of the newly associated Member States of European Union rely heavily on efficient sea transportation systems. One of the major factors is their geographical location. Most of these member states (Poland, Lithuania, Latvia & Estonia) lie on the east coast of the Baltic Sea. Giving them instant access to the sea. With several hundred years of history in Sea Transport, all of these countries have very well established small to medium size ports (SMPs). Considering the growing demand for consumer products and transhipment facilities in the light of the European Union's expansion, development, the growth of these ports is imperative.

Considering this increasing demand for transhipment facilities, a planning and design software tool is required. Ports can use this tool to evaluate the different strategic options of expansion and operation in a short period of time and without excessive spending or interruption of their operation.

The Port Process Simulator (PPS) described in this paper suits this task. The development of this system was carried out initially under the EU sponsored RTD projects SPHERE (FW4) and continued during the IST project BALTPORTS-IT (FW5).

Based on development work done under SPHERE, the software was reviewed, considerably enhanced, and to a large extent rewritten. The Port Process Simulator, in its present form, is part of the BALTPORT-IT project.

The paper is organised as follows. Section 2 introduces the Port Process Simulator. In Section 3 the architecture of the PPS is discussed, emphasizing the business model, simulation technique, approach and behaviour of the architecture. Section 3 also briefly discusses the animation model of the simulator. The results, and usefulness of this application to ports, are described in Section 4. The Industrial Applications of the PPS in three Baltic Ports contributes to Section 5. Concluding remarks and future work are presented in the final section, which is followed by references.

2. THE PORT PROCESS SIMULATOR

The ideology behind the Port Process Simulator is that: "A single software system in the form of a generic, customisable shell can simulate a complete port and its processes, i.e. infrastructure, suprastructure, aquastructure, equipment and the movements of ships and land vehicles". The simulator software can be applied to any port with a mere introduction of picture files of the port's approaches and its layout. This is complemented by port specific input data related to vessels, land vehicles and cargoes. Populating the shell of the Port Process Simulator customises it to mimic the port under investigation.

The input data focuses on six areas. It adapts the generic simulator software completely and thereby makes it port specific. Data is fed into the simulator in the following sequence to build the computer model of the port of interest:

1. Cargo Flows
2. Transportation Modes
3. Transportation Vehicles
4. Port Layout
5. Cargo Handling Facilities
6. Port Regulatory Environment

Figure 1 below depicts the black box approach taken in the development of the PPS.

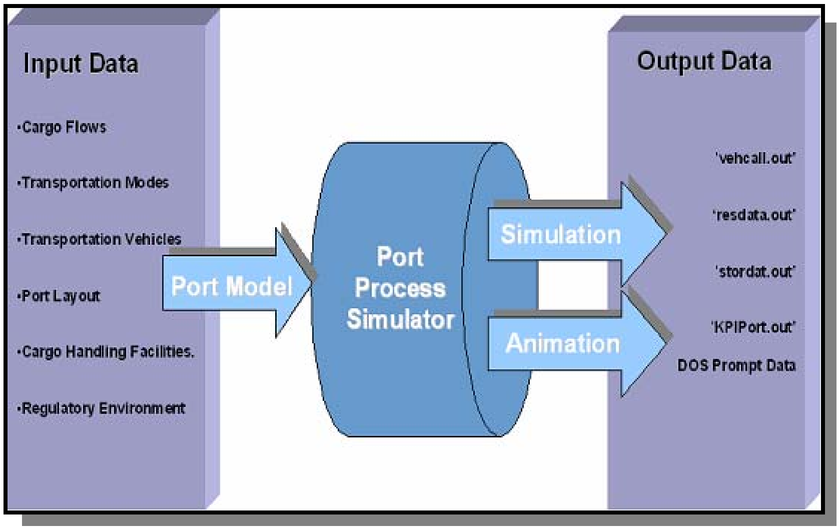

Figure 1 The Port Process Simulator Black box Model

A cascading menu system as shown in Figure 2 is used to select and enter cargoes passing through the port together with their associated transport characteristics. Customisation proceeds by building in sequence: the maritime access, the layout of the port proper and the land access to the port.

The port is then populated with the equipment and vehicles needed to effect the flow of the initially selected commodities according to transport mode. Elements from a cascading menu system can be selected to build the port specific model.

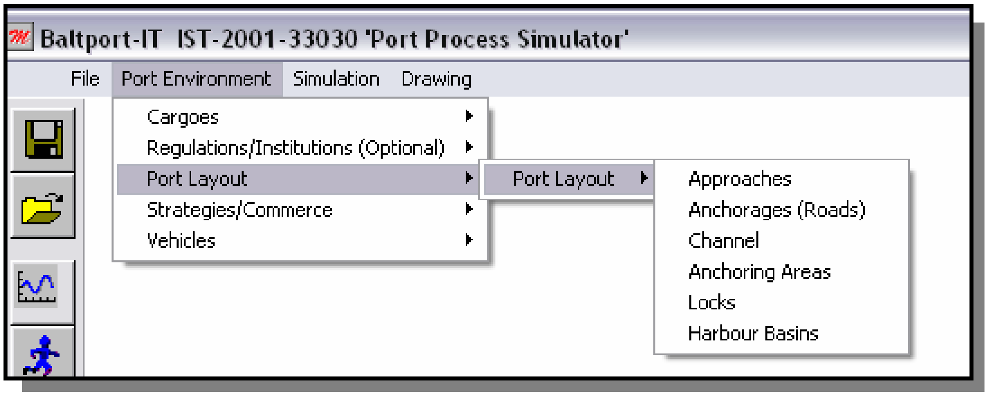

Figure 2 The Cascading Menu System of PPS

During this process the simulator continuously checks that the correct facilities, equipment and vehicles are defined based on the transport characteristics of the commodities selected at the start of the modelling and customisation process.

The output from simulation runs is gathered in five designated files for preparation of the raw data, subsequent statistical analysis and evaluation using spreadsheet type programs, e.g. MS-Excel or MS-Access.

3. THE ARCHITECTURE

3.1 The Business Model Of The Port

The exchange of the minimum yet correct information in a port or terminal is the key to the physical movement of goods to and through the port or terminal and the associated handling of the cargo between modes of transport and or modes of transport and temporary storage. The port business model is a combination of two cycles namely import and export. A cargo-carrying vessel that brings in import cargo carries export cargo on departure. This complete cycle of import and export is shown in the Figure 3.

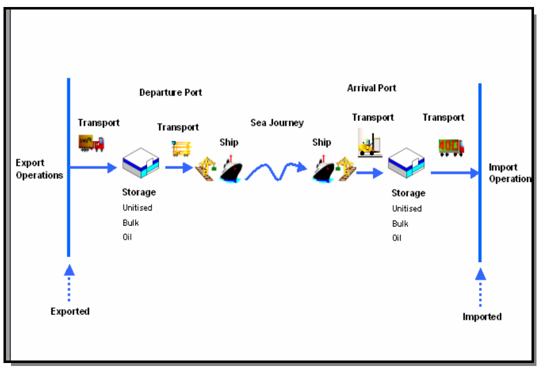

Figure 3 The Import Export Cycle

The activities and processes involved in the import and export of cargo are sequential and stochastic and in some cases run parallel to each other. They lead to the presentation of the top-level business model of the port as indicated by Figure 4 below.

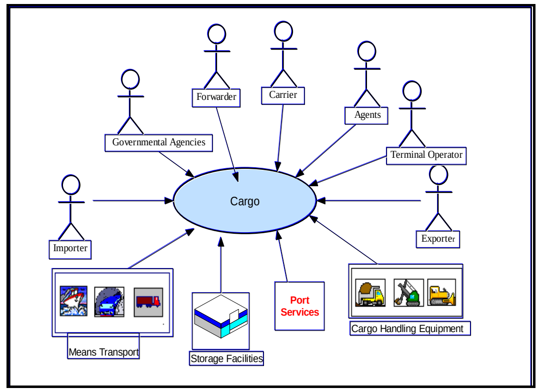

Figure 4 Top Level Business Model Of the Port

3.2 Discrete Event Simulation Approach

The ***discrete event simulation approach*** adopted enables modelling of the system as it evolves over time by representing the changes as separate events. There are numerous ways of describing the mechanism of the logic within discrete event simulation. Pidds [7] describes them in detail. This has been followed up by other researchers, e.g. [8]

Event scheduling is the first way simulations were developed. An *event* is anything that changes the system statistics (also known as the *state* of the system) other than the mere passage of time. The essential idea of event scheduling is to move along the time scale until an event occurs and then, depending on the event, modify the state of the system and possibly schedule new events.

The arrival and departure of vessels at a port occur at distinct points of time. This is referred to as *events*. The number of events occurring in a port is finite; thus the discrete event simulation approach offers the best fit.

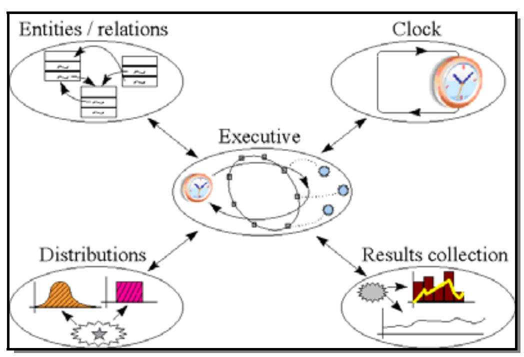

Figure 5 Structure of the Discrete Event Simulation as used by PPS (adapted from Kreutzer, 1986)

Appropriate probability distributions generate random times, which are needed in order to generate the service times, and the arrival times required by the scheduler.

Based on this, it is an uncomplicated exercise to run through the simulation of the Port Process Simulator. The events are stored in an *event queue*, which lists all events in order of occurrence. The first event in the queue is taken off, and other events may then be added, assuming that an event only triggers other events in the future.

3.3 Process-Orientated Approach

The model of the simulator is based on a ***process-orientated approach***. It is built by first transcribing the processes which occur in a port in its real environment into the logic that subsequently governs the behaviour of the simulator.

To accommodate this process-orientation, the "if-else" statement is extensively used together with a combination of calculations related to port operations. The port turnaround time of the departing vessel and the allocation of the same berth and cargo handling resources to the next ship may serve as examples.
The process-oriented approach used by the simulator mirrors the sequence of activities and processes taking place in the port and focuses on each one of these in turn.

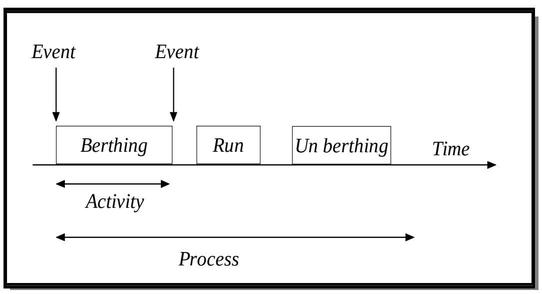

Figure 6 Model Logic of Berth-Process

Figure 6 shows the 'Berthing' process as an example. Events are normally *paired instances*, e.g. start of berthing and end of berthing. Activity is describing the *duration*, e.g. 'Berthing', and is very similar to the pair of events. The process combines the collection of events or activities together and mimics the *life cycle* of the entity; in this case 'Berthing'. This approach of process-orientation applied in the PPS is less commonly used in simulation software and requires more planning to implement it. The 'concern net' developed in the SPHERE project forms the bases of this planning. Because of the robustness of the 'concern net' the process–oriented approach becomes very efficient.
Figure 7 below shows the different processes on the shore side as they may take place on any one of the terminals in a port.

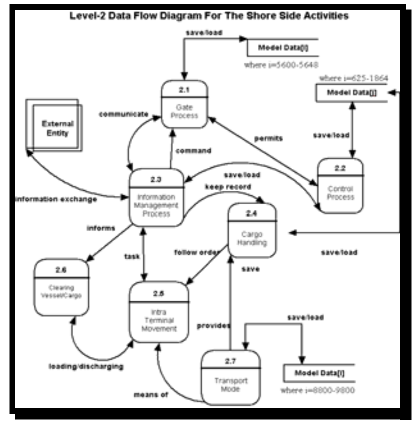

Figure 7 DFD for the Shore Side Processes

3.4 The Stochastic Behaviour

Stochastic Models operate with random input – like a terminal with randomly arriving cargo consignments from the hinterland requiring varying service times. Taking samples from appropriate probability distributions facilitates the ***stochastic behaviour*** of the discrete event model of the simulator. Modsim-III provides a library of comprehensively defined statistical functions and distributions. These inbuilt distributions are used to represent the random input.

3..5 Animations

The Port Process Simulator provides the animation of the Simulated Port Model using data visualisation techniques. The animation adds an important additional dimension to the Port Process Simulator, enabling an understanding of data that is virtually impossible to obtain by viewing still images. Animation mimics the behaviour of a ship entering the harbour, the movement of trucks and cargo handling equipments in the port, arrival of trains on the platform and display of measurements of physical variables in space and time.

The Port Process Simulator uses a function based unified data model to produce its animation. Using the function mapping techniques, the PPS adjusts the coordinate systems related to different views of the port or terminal. The background graphics used in the simulator are connected to the port's co-ordinate system as shown in the map of Figure 8. This is done when the approach- and port maps are viewed for the first time during the model building session.

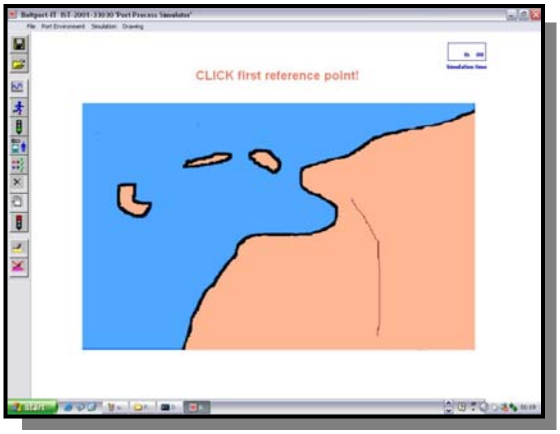

Figure 8 The Synchronisation of the System of Coordinates

The first time the option 'Show Approaches' is used, the background graphics become visible and the user is prompted to click the first, second and third reference points as indicated in Figure 8.

The user is then requested to enter the real world value read directly from the navigational chart used, using the interface as shown in figure 9. These two coordinates systems of 'over-view' and 'detailed view' are then synchronised using a function mapping technique. The simulation deals mostly with distances between coordinate points. Small deviations from the exact positions do not have a colossal effect on these distances nor do they adversely affect the performance of the simulator.

Figure 9 The Real World Coordinates

3. 6 Results of Simulation

The model made with the PPS can be simulated for design, procedural analysis, operational efficiency and evaluation of any port. Some 66 efficiency related factors can be extracted as a result of the simulation.

The simulation results are saved in five different data files. These files contain categories according to Vehicles, Resources, Equipment and the Key Performance Indicators of the port.

4. THE APPLICATIONS

4.1 How Port Personnel Can Use The Results

The Model of a port is a web of interwoven events and activities. In essence any change in the port will have a domino effect rippling throughout the port. In order to see, how the Port Process Simulator can accommodate the user, two scenarios have been developed.

The main aim of the research is to investigate the impact of taking the 'load off the roads' and replacing it with sea and rail transport as advocated by the European Commission. However, this change comes with its own repercussions. For this reason the following two scenarios were developed to simulate possible consequences of this change.

Scenario 1: A container terminal with three berths, good road access and railway sidings from the terminal to apron, container freight station and warehouses directly linked to the main rail routes and working a two shift system was modelled. At present 7% of the annual throughput of some 130,000 TEU are moved by rail whilst 93% are entering and leaving the terminal by road. In this SMP the parcel size amounts to between 150 – 700 TEU per ship call. The terminal is equipped with 2 ship-to-shore gantry cranes, 4 straddle carriers working the container yard and 4 reach stackers working the rail terminal within the container terminal. A uniform distribution was applied to control the vessel call frequency. The road to rail ratio was initiated with 100 percent transfer by road and zero percent by rail. Eleven runs of the model were made by keeping all the variables fixed and changing the road to rail percentage in units of tens until a zero percent transfer by road and 100 percent transfer by rail was achieved. The models were simulated for 30-day periods with the initial aim to transfer containers from road to rail using the existing cargo handling facilities to ascertain how this transferring cargo from road to rail would affect the terminal's performance in the light of an anticipated increase in demand for cargo throughput.

The simulator produced the results depicted in Figures 8 to 10 below.

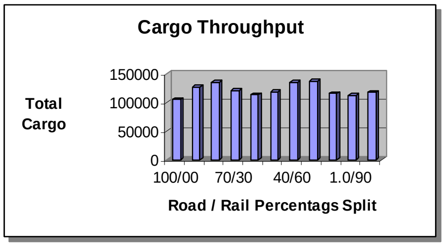

Figure 8 Cargo Throughput – Scenario1

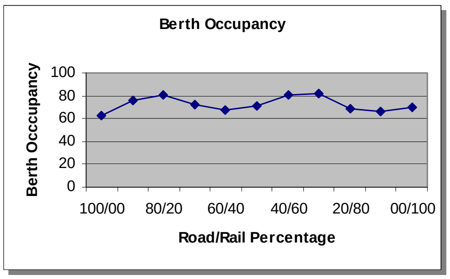

Figure 9 Berth Occupancy – Scenario 1

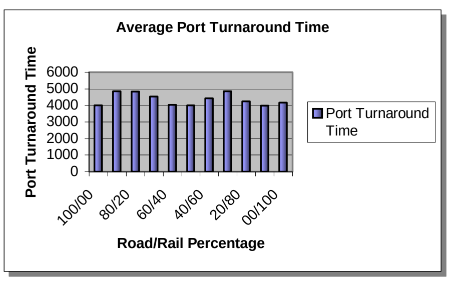

Figure 10 Port Turn-a-Round Time – Scenario 1

Considering the output of the simulation of the present terminal facilities as expressed by port turn-a-round times indicates, that there are two feasible solutions. Both involve considerable upgrading of the rail access to either a 40/60 or a 10/90 percent road/rail split. However, the criterion of port turn-a-round times cannot be regarded in isolation, but has to be considered together with cargo throughput and berth occupancy. Cargo throughput indicates that the 40/60 split of road/rail is the most favourable and rules out an increase of rail transport to 90%. However, under the 40/60 split, berth occupancy is rising to above 80% with the consequence of congestion and waiting of vessels due to a shortage of berths. The apparent solution, an extension of the quay and another berth involving heavy and expensive civil engineering work of, e.g. quay construction, dredging, back filling and surfacing. The question arising is: "Is this really the best possible way of solving the problem of 'too much cargo and too little terminal'?"

To answer this, Scenario 2 was developed in the same way as Scenario 1 except that the capability of terminal's cargo handling equipment was doubled in comparison to that selected for Scenario 1. A uniform distribution was applied to control the vessel call frequency. The road to rail ratio was initiated with 100 percent transfer by road and zero percent by rail.

Again, 11 runs of this model have been made, keeping all the variables fixed and changing only the road to rail percentage in units of tens until a zero percent transfer by road and 100 percent transfer by rail was achieved. Again the models were simulated for a 30-day period with the aim to determine to what extent it would be beneficial to increase the rail access to the terminal and to transfer containers from road to rail in conformity with the EU recommendations as outlined in the EC's White Paper "European Transport Policy for 2010: time to decide", September 2001. The results are depicted in Figures 11 to 13.

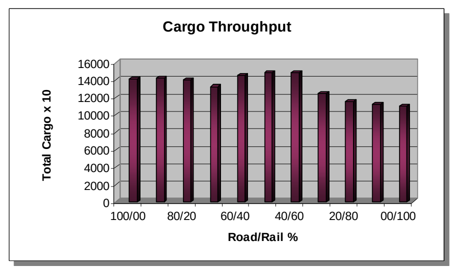

Figure 11 Cargo Throughput - Scenario 2

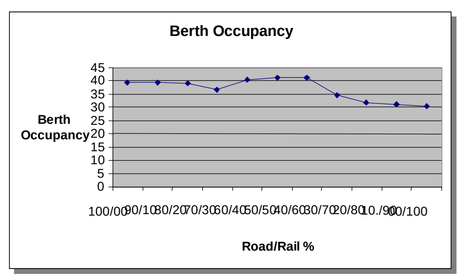

Figure 12 Berth Occupancy - Scenario 2

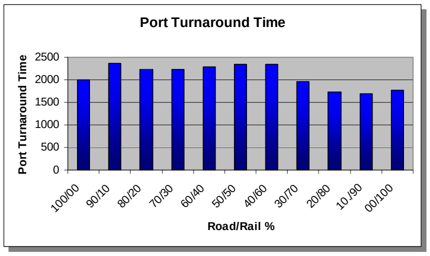

Figure 13 Port Turn-a-round Time

The simulation results of Scenario 2 yielded the following recommendations:

- Double the terminal's capability of cargo handling by changing to more efficient gear.
- Accept the road/rail split to be 40% by road and 60% percent by rail and considerably improve the rail transport capability of the terminal.
- Change the current shift pattern of working from two shifts per day to three shifts per day.

If this is done, the anticipated cargo throughput of some 140,000 TEU p.a. can be accommodated using existing facilities. Berth occupancy decreases to about 40% due to increased terminal efficiency. Ship turn-a-round time decreases. There is no need to extend the quay length and add a fourth berth. Changing the cargo handling facilities on the terminal is substantially more economically attractive than lengthening the quay and adding another berth. This solution is also considerably less interruptive to present terminal operations.

The conclusions from comparing the results of the two scenarios are that: rail access to the terminal should be substantially improved and used in favour of road transport to and from the port. No new berth is needed even though the terminal in question is a busy one.

5. INDUSTRIAL APPLICATION

The PPS has been successfully applied to the ports of Gdansk, Klaipeda and Riga. Screen prints of the simulator runs demonstrate this universe applicability of the PPS.

5.1 Port of Gdansk, Poland

The PPS was successfully installed at the Port of Gdansk. The University of Warsaw has used the simulator as a tool in their work to investigate possible improvements of the logistics processes at the Gdansk Container Terminal. The Chapter - "Simulation-based improvement of logistics processes at the Port of Gdansk" of the BALTPORTS-IT project handbook discusses this work and its results in some detail. Figure 14 below shows an areal- and the simulator view of this port.

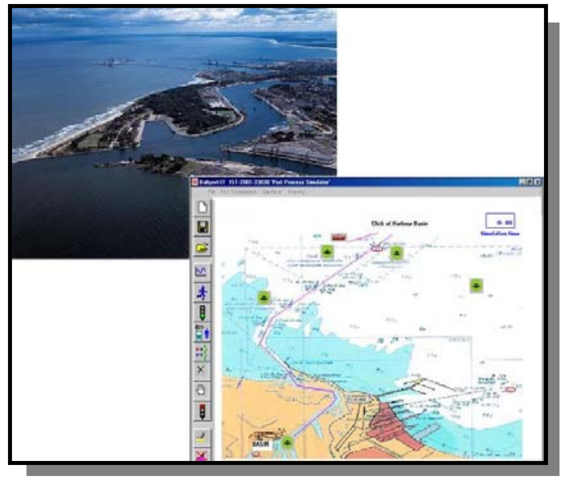

Figure 14 PPS Presentation of the Approaches to the Port of Gdansk

5.2 Port of Klaipeda, Lithuania

The PPS has been installed and modelled for the NAFTA Oil Terminal and the KLASCO Container Terminal in Port of Klaipeda, Lithuania.

5.3 The Port of Riga, Latvia

The PPS was installed, customised, tested and run at the Baltic Container Terminal in Riga, again as part of the EU sponsored BALTPORTS-IT project.

6. FUTURE WORK

The Port Process Simulator is generic simulation software that can be used in any port with a mere inclusion of the Port's map followed by customisation of the simulator.

It delivers a good insight into the operation of the port/terminal using different modes of freight transport to and from the port/terminal and different selections and capabilities of cargo handling equipment. It is possible to use it to 'relocate' terminals seawards or to extend the port facilities by building new ones and investigate the effects on port/terminal throughput, port turn-a-round time of vessels and berth occupancy. However, the PPS does not allow the user to simulate and study the activities on the terminal proper. For this reason, work is in progress to develop and eventually include a 'Terminal Planning Board' into the PPS. This Terminal Planning Board (TPB) has been developed under the EU sponsored project TRAPIST with the objectives to develop tools and routines to assist port and shipping to become more effective. The basis of the TPB is the 'concern-net'

(Schmidt 1997), that is very robust and led to an object oriented, relational database combining the information needs of consignors, consignees, freight forwarders, land and maritime carriers, ports and terminals as well as authorities. The DB enables bypassing the often conflicting information needs of the partners and modes involved in the freight transport logistics supply chains or better networks. Similar to the PPS, the TPB uses maps or engineering drawings as working background to assist the exploration by port personnel of different layouts of the terminal and different selections of cargo handling gear depending on the cargo handled. In essence the TPB integrates the professional know-how and experience of the port/terminal operator with the combinatorial capability of the modern computer to improve terminal efficiency and thus make the gateway under investigation commercially more attractive to shippers, exporters, importers, assist in regional development and transfer cargo away from road transport to using the 'Motorways of the Sea'. Figure 14 below offers an impression of this Terminal Planning Board.

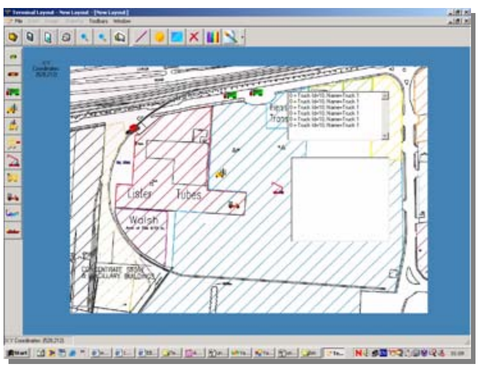

Figure 14 The Terminal Planning Board of TRAPIST

Apart from displaying the terminal as background, the user is able to develop new layouts by drawing them, populate the terminal with different cargo handling gear, draw the paths cargo handling gear, terminal vehicles, information and people are travelling to, from and on the terminal, measure distances, safe, retrieve and edit previously worked on layouts or change the equipment used by selecting others from menus and drag and drop them into any desired position.

7. CONCLUSIONS

A suitable solution has been found to the combined problems of transferring cargo from road to rail and an anticipated increase in demand for transhipment in line with the anticipated economic growth of the region. The recommendations allied to this solution are: extending the rail facilities in the terminal to accommodate a split of 40% road and 60% rail. Double the efficiency of the cargo handling equipment on the terminal by replacing 'dated' equipment and changing the working practice from two shifts- to three shifts per day. In this case neither an extension of the quay nor an additional berth are required. As indicated, the PPS does not enable the user to investigate the detailed workings of the terminal. The ongoing research and development work on the TPB will enable this to be done and the results are very encouraging.

Whilst a lot of terminal operations related work can be solved by common sense and experience, i.e. TPB, the integration of human intelligence with the combinatorial capability and the processing speed of the modern computer promises further and substantial gains in efficiency with the key enabler being information technology.

REFERENCES

[1] – EU-Contract No. WA-95-SC.224, January 1997 SPHERE Deliverable 5: Report on the Preliminary Activities To Port Process Re-engineering of the SPHERE 'SMP Operation Simulation Program', Schmidt, F. A. et al., 1997.

[2]- Arsham, H., 2000, "The Use of Simulation in Discrete Event Dynamic System Design-Journal of System Sciences, 31(5), 563-573.

[3]- Stevens, P., and Pooley, R., 2000, "Using UML-Software Engineering with objects and components" - Updated Edition-Addison Wesley-2000

[4]- Results of the IST-2001-33030 Project BALTPORTS-IT "Applications Of Simulation And It-Solutions In The Baltic Port Areas Of The Associated Candidate Countries"

[5]- Yazdani, R., and Schmidt, F.A., 2003, "Deliverable D41-The Port Process Simulator User Guide", BALTPORTS-IT
IST-2001-33030 Project.

[6]- Matthes, F, Wegner, H., and Hupe, P., June 1999. "Process-Oriented Approach to Software Component Definition", TU Hamburg, Germany, CASE*99.

[7]- Pidd, M., 1992."Computer Simulation in Management Science". Wiley

[8]- Ball, P., 1996, "Management and Control: Tools in Action" Algarve, Portugal. 15th - 17th May 1996, pp. 367-376. - 2nd DYCOMANS workshop.

[9]- Schmidt, F. A., 1997, "Report on the Preparatory Activities for SMP Process Re-engineering: - The development of the generic concern net and its

application to the four SPHERE ports" Internal report to the SPHERE Consortium. June 1997, pp. 40.

[10]- Kreutzer, W. 1986. *Systems Simulation - Programming Styles & Languages*. Addison-Wesley.

[11]-John Stasko, John Domingue, Marc H. Brown, Blaine A. Price, "Software Visualization". 1998

[12]- Hibbard, W., C. R. Dyer and B. Paul. *A Lattice Model for Data Display*. Proceedings IEEE Visualization '94 Conference, pp. 310-317, October 1994

BIOGRAPHIES

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Dr F A Schmidt (Captain): 1966, Master Mariner. 1973, BSc Nautical Studies (CNAA) London. 1984 PhD in Naval Architecture (CNAA) London. Member of the Nautical Institute, Member of the Royal Institution of Naval Architects and Fellow of the Institute of Freight Professionals. Some 20 years of sea service on general cargo vessels and bulk carriers followed by working as ship manager preceded present academic, research and consultancy activities. Besides other contracts, Dr Schmidt was an active partner in industrial as well as EU and EPSRC sponsored RTD projects, e.g. SPHERE, TRAPIST, BALTPORTS-IT, and ITeLS. At present he heads Maritime & Supply Chain Solutions (Europe) Ltd, a consultancy company specialising in maritime transport logistics, supply chain solutions, port operations and allied IT solutions.

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Fred Kamperman: Terminal manager of 'Baltic Container Terminal Ltd.' in Riga (Latvia) since January 1997. He graduated from the Nautical College in Rotterdam (The Netherlands), made a career at sea as a deck officer and has worked the last 25 years in managerial positions at several maritime terminals directing break bulk- Ro-Ro and container operations. From 1991 to 1996 he was Operations Manager of the Freeport Terminal in Malta. He specializes in port and terminal consultancy (own company) and participated in various European Projects related to port and terminal simulation and logistics falling within the several IST frameworks of European Commission.