VISUALISING LAYOUT AND OPERATION OF A CONTAINER TERMINAL

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ABSTRACT

The proposed paper summarises the work done in WP4 of the EU sponsored RTD project TRAPIST where the needs of small to medium sized ports / terminals with 'multi-purpose' capability had to be addressed. To this end the following had to be considered:

- The absence of extensive IT support and how to deal with it,
- Information flows to/from and within the terminal,
- Cargo flows to/from and within the terminal and in association with this,
- Layout of land and maritime approaches including berths,
- Position of in-and out gates,
- Terminal and yard layout in conjunction with selected cargo handling equipment.

The above resulted in an electronic terminal planning board (TPB) with generic applicability. This TPB was successfully applied to visualise initially the Status Quo and subsequently to explore possible extensions of the Tivoli Container Terminal in the Port of Cork, Republic of Ireland. It was further used to review and improve the layout of the road infrastructure in the Port of Kokkola, Finland.

INTRODUCTION AND CONTRIBUTION TO EU POLICIES

Implemented and pending European polices are a common denominator for ports. This is particularly applicable to small and medium sized ports, which as a consequence of the European Spatial Development Perspective (DETR,200) and The Common Transport Policy (CTP) (European Commission, 1992) transposed into national law, benefit from the resulting national and regional spatial development and transport plans.

These policies favour polycentric and regional development as clearly identified in the EU sponsored North European Trade Axes Study (NETA, 2002). Small to medium sized ports were found to play a crucial part in this development process by serving as regional logistics nodes and gateways in conjunction with short sea shipping and / or ferry services. The commercial attractiveness of these gateways, through operational efficiency supported by the physical development of associated facilities, their land and maritime access, is crucial to the economic development of the regions.

The European Commission (EC) in its publication “Time to Decide – 2010” (DGTREN,2001), the White Paper of September 2001, reviewed the results of the implementation of the CTP. It revealed the EC’s plans of how the CTP can be further and successfully implemented within the framework of ‘Sustainable Development’ and actions to achieve the all-important ‘Balance of the Modes of Transport’. In this respect the development of Freight Corridors, Motorways of the Seas and the removal of bottlenecks were identified as being of particular importance. Combining Short Sea Shipping (SSS)’ and ‘Rail’ with ‘Road’ offers long-distance and pre-/post-carriage respectively. This brings the operation of terminals, the ship-shore interface, and associated bottlenecks into play.

Despite considerable improvements and growth in SSS, port turn-a-round times of container feeder vessels need to be further reduced to offer a transit time more comparable with those of the combination of road and ferry transport. The EC Fiches “Bottlenecks in Short Sea Shipping”, e.g. April / May 1999 (DGTREN,1999), that discuss bottlenecks and possible solutions indicate that port turn-a-round time can be reduced by ensuring that terminal operations are more efficient and that access to terminals conforms with the access, parking, manoeuvring and berthing requirements of road and rail vehicles as well as ships accessing the port or terminal from land and from sea.

The need to improve ‘Terminal Efficiency’ has been addressed amongst others during the execution of the 5th EU sponsored 5th FWP project TRAPIST. Of

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particular interest for this paper is the contribution made in Workpackage 4 with the aim of "Developing Means for Gathering and Intelligently use Data from Identified Sources". These "means" comprise of an "Object Oriented, Relational Database" and an "Electronic Terminal Planning Board". Together they addresses in a very comprehensive way the bottleneck 'Port' described in the EC publication "COM99 317 en final Development of SSS in Europe", 1999 (EC, 1999), where short comings of port infrastructure and port efficiency were commented upon and 'port turn-a-round time' was singled out as one of these inefficiencies. WP4 proposes "Means" aimed at increasing the efficiency of small to medium sized ports by specifically increasing their commercial attractiveness to regional exporters and importers. This proposition can be achieved by improving the flow of information, cargoes, vehicles and people through the port or terminal. Correct and timely information is the first of two key aspects of this. Solving operational problems quickly and effectively by visualising them, simultaneously enabling the port / terminal operator to easily explore alternate solutions by using common sense based on experience is the second key aspect. Both are paramount to achieve the transfer of the flow of goods away from the at present prevailing mode of 'Road' using heavy goods vehicles (HGV), to water-borne transport, particularly to the 'Motorways of the Sea' employing short sea shipping as an attractive alternative mode of transport as envisaged by the CPT of the European Union (EU). The benefits of this will affect port communities and port hinterlands throughout the EU from the Mediterranean to the Baltic including those of the New Member States and further to the East.

OBJECTIVES AND ACHIEVEMENTS

Workpackage 4 (WP4) of TRAPIST had the following major objective:

- To develop a methodology for data gathering and its general representation to visualise and resolve operational problems in ports and terminals.

This major objective was achieved and took the form of:

- An object oriented relational database and, based on this,
- An electronic terminal planning board.

The development of a "Methodology for Data Gathering" resulted in the above indicated object oriented relational database. Microsoft Access was used as a development tool and the proposed "Methodology" took the shape of a database comprising of the minimum information required to address the combined efficiency of the flows of information, cargoes, vehicles, ships and people to and from the hinterland of a port or terminal and, through this logistics node to destination. The methodology developed is equally applicable to seaports, inland ports, rail terminals, logistics centres or freight yards. In outline, the "Methodology" consists of:

- An object orientated, relational data model in Microsoft Visio format.
- A data dictionary in HTML format, and based upon these two components,
- An object orientated, relational database using the framework of Microsoft Access without as yet specific user applications apart from those of the 'terminal'.

THE DATABASE

The data fields in the database encapsulate the information required to plan, organise, facilitate and manage international multimodal freight transport logistics including port and terminal operations. Thus they identify the transport characteristics of cargoes including codified data and international standards, e.g. ISO container number, tariff codes, UN country codes, EU transit references and the Unique Consignment Reference (UCR) number each shipment requires. Data fields contain information that enables the user to delineate the layout of ports and terminals including container stacks and marshalling areas. Information contained in the data fields also identifies and describes, cargo handling equipment, vehicles and routes used within the port or terminal as well as particulars and messages passed as well as manpower requirements pertaining the working practices of the terminal / port of interest. Particular attention was given to the EU sponsored projects of BALTPORTS-IT, SPHERE, TRIM, INFOLOG, BOBCOM, EUROBORDER, D2D, THEMIS, INTRA-SEAS and INTERPORT. Apart from the above listed ones, 24 FP4 and six FP5 projects were examined with emphasis on freight transport related data and data models used. The ensuing information formed the basis for this work and the resulting data model gives a comprehensive, object-oriented view of international, multimodal transport logistics processes as well as port / terminal operations. It offers a database independent description of what should be stored and how to store it. Making the data model comprehensive and generic enables it to act as the basis for the Electronic Planning Board application that will facilitate terminal operations.

The possibility of maintaining compatibility with other "user applications" such as a simulator, e.g. the simulator initiated as part of the SPHERE project and further developed during the BALTPORTS-IT project come to mind.

Figure 1 below offers an appreciation of the data model.

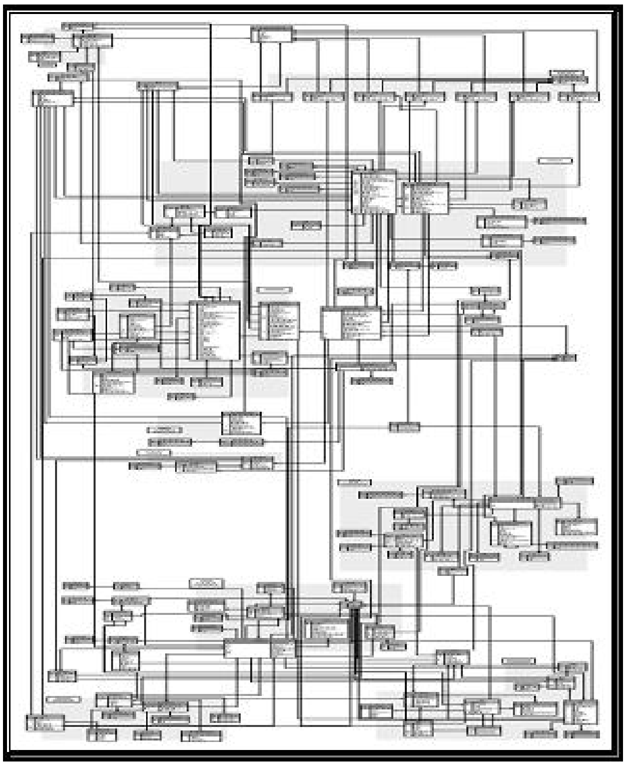

Figure 1: An Impression of the completed "Object Oriented Relational" Data Model

THE TERMINAL PLANNING BOARD

The objective of WP4 required the development of:

- A computer based methodology in the form of an 'electronic terminal planning board' (TPB) comprising of a set of building blocks depicting:
  - Plan view of the maritime access, the berth, the apron, the container yard, the gate and the land access to the terminal – road, rail and inland waterways.
  - A selection of cargo handling equipment, container stacks, ships and road vehicles.
  - Items of information that trigger activities.
  - Links and nodes representing the movements of, e.g. cargo, vehicles, information and people through the terminal.

In all, a visual means to use common sense as well as offer the possibility of simulation to solve operational, equipment and layout problems of small to medium sized ports and terminals.
The TPB's design comprises of six modules. They were designed, programmed, tested, peer reviewed and validated as standalones. However, when combined they form the complete Terminal Planning Board as shown in Figure 2. Moving from left to right, the normal sequence of events, as they occur on a terminal when engaged in exporting, was followed. The reverse is true for importing.

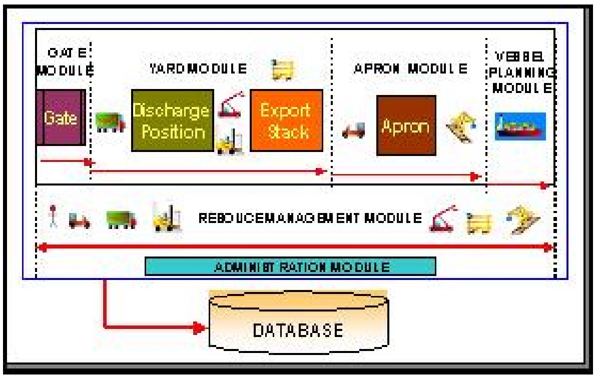

Figure 2: The Modular Program Structure of TPB

All modules depicted in Figure 2 follow the *3 –Tier Distributed Approach* by implementing the *Client/Server* communications model in *Fat Client Configuration* as Figure 3 below outlines.

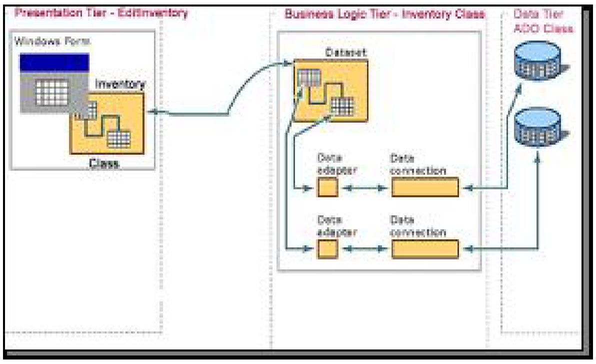

Figure 3**:** The 3-Tier Design

This distributed architecture allows the Terminal Planning Board application to run on multiple computers whilst the database resides on the main server. The benefits of this approach are:

- Events happen concurrently, thus more can get done.
- By replicating functionality, a more robust service can be provided.
- Users and other actors in different locations can readily be served.
- Not all the functional nodes need to be operational at once.
- Diverse systems may be connected.

At the design stage, the TPB has been deliberately given the added potential capability for it to be used as a means of communication for the port community. This makes the TPB a business application in which the various steps in the business processes can be located at the most efficient places in a network of computers. In the typical transaction using the 3-tier model, user interface processing is done in the PC at the user's location, business processing is done in a remote computer, and database access and processing is done in yet another remote computer providing centralized access.

Figure 2 shows that the backbone of the structure of the Terminal Planning Board is the object oriented relational database. To date, this database comprises of some 1,300 entities residing in some 130 tables. In an application that is supported by a large database, simultaneous access by different users and from different computers as indicated, correctness of data must be ensured.

To eventually be useful in every-day operation, the prototype of the TPB has been designed with three purposes in mind not all of which have as yet been implemented due to resource and time limitations. However, to draw attention to the latent potential of the TPB, these three purposes are:

The Planning Mode: In this case information gathered from identified sources relates to terminal layout, cargo handling equipment and vehicles. Data can be entered, stored in and retrieved from the database. This information can be superimposed onto a map or engineering drawing showing a plan view of the terminal to depict a current or planned layout of the terminal of interest. This has been implemented including the required application specific graphical user interfaces (GUI) enabling the TPB to communicate with the database and is fully operational.

The Operational Mode: In this case the application of the TPB is biased towards the daily operation of the terminal. Again, this requires the TPB to gather data from identified sources, i.e. from freight forwarders, hauliers and other members of the port community, and store it in the database. Operations relate to gate, yard, storage, apron and discharging and loading as well as tracking and tracing activities. The GUI enabling communication between the gate and the database have been developed and are operational including the allocation of 'storage space' as opposed to 'ground slot space'. The application specific GUI enabling the members of the port community to directly communicate with the TRAPIST database do not yet exist but are mentioned and form part of the latent potential of the TPB.

The Simulation Mode: In this case, the simultaneous activities of the gates, the yard, the apron and the vehicles could be simulated using terminal specific distributions in conjunction with pseudo random numbers and the animated icons of, e.g. vehicles, cargo, cargo handling equipment, information and terminal staff in order to generate dynamic information of benefit in the management of the terminal. This use of the TPB too is part of its latent potential. The link between TPB and the simulation is again the object oriented relational database.

The following may serve as examples of the latent potential once the 'operational mode' of the TPB is fully implemented:

- The central controller of the port or terminal is accessing the database to query empty stack positions.
- The in-gate keeper and the central controller are simultaneously accessing the database regarding access, drop-off positions and storage location in the export stack for containers to be delivered to the port /terminal for export under, e.g. the 24 hour rule.
- The stevedore or the central controller and the cargo handling equipment operator are simultaneously accessing the database to place, receive or confirm an order to deliver an import container to a specific loading position for road tractor trailer units or to deliver an export container to a specific storage position in the export stack or on the apron in readiness for loading.
- The freight forwarder accesses the database to transfer information concerning export cargo and / or to trace the progress of export or import cargo.

The TPB uses the extended modelling language (XML) language to pass data between the modules of the TPB, the database, and the computers of individual and concurrent users. XML is a text-based protocol. It can describe any type of data, even images. Using XML format, data can be moved easily and reliably between modules and layers in three-tier applications, between different operating systems, to and from databases and using the Internet, between different users of the port community. The application of mobile computing using web messaging in conjunction with XML make it possible for terminals and other actors of the port community to communicate easily and effectively exchanging data as events occur, i.e. in real time.

Figure 4 below portrays the TPB and offers some insight into its functionality. It shows the menu bar to control the operation of the TPB at the top of the screen. The tool bar or 'toolbox' is placed on the left hand side, and the status bar including management information are included at the bottom of the screen.

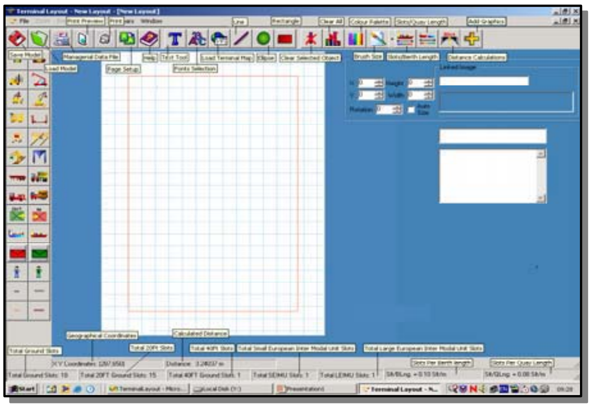

Figure 4: The Terminal Planning Board

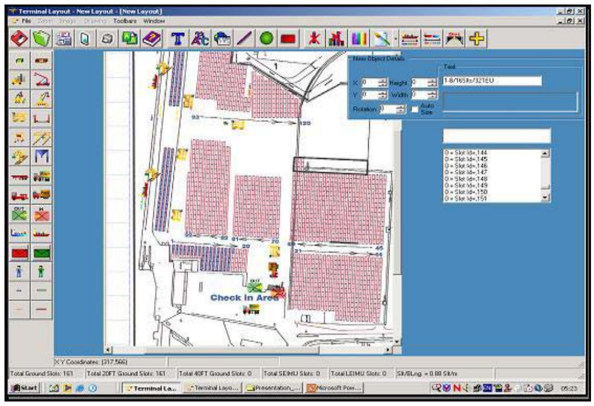

Figure 5: The "Status Quo" of the Tivoli Container Terminal in Cork – TEU only

TESTING OF THE TERMINAL PLANNING BOARD

The objective of this RTD work implied testing the capability of the TPB by at first representing the "Status Quo" of the Tivoli Container Terminal in the Port of Cork, Republic of Ireland, and of the Port of Kokkola in Finland, as they existed at the start of the TRAPIST project in 2002. The status quo had to be conveyed by means of the physical flows of cargoes, the equipment used and the messages passed. This had to be superimposed on the plan view of the Tivoli Terminal as well as the map of the Port of Kokkola.

Apart from access, gates, ground slots, cargo handling equipment and vehicles the presentation indicates a network of paths forming links and nodes, over which cargo, equipment and information flow. This information is stored in the TRAPIST database and in conjunction with simulation (WP5) it will show traffic density, path service level, origin-destination service level and the distribution of flow over paths and thus possible bottlenecks. The objectives of Task 4.3 were achieved but involved:

- To prepare the plan view of the terminal, including maritime access, berths, apron, container yard, gate and land access, under consideration for display on the screen.
- To use the drawing tool and icons to depict paths and positions of cargo flows, equipment and associated movements, storage areas and information.

Figure 5 below shows the results related to the "Status Quo" of the Tivoli Container Terminal. It indicates the layout of TEU ground slots spaced for "2+1" straddle carrier operations. It shows the in- and out-gates, road access to the check-in area, the quay including the two berths, the ship-to-shore gantry cranes, the apron, the road access to the apron, straddle carriers and articulated vehicles delivering and / or collecting containers.

The bottom four icons in the tool bar on the left hand side of Figure 5 represent ground slots. The top two mimic the space required by a 20 ft (TEU) on the ground of the terminal and by a 40 ft (FEU) container respectively. The bottom two icons block out the ground space needed by the European Intermodal Loading Units (EILU), proposed by the Commission. These EILU are based on the dimensions of swop bodies. They maximise the space for the stowage of pallets, something ISO containers do not do, and, as a result, these EILU have different space requirements to ISO containers on whose dimensions ground slots are traditionally based. To achieve the terminal layout shown in Figure 5, each ground slot had to be individually selected from the tool bar, entered into the database, positioned on the screen, dragged and dropped into position and aligned by rotation. The TPB uses 'left' mouse clicks to select, drag and drop an icon, 'right' mouse clicks to rotate the icon, and wheel rotation to zoom in and zoom out.

The objective of WP4 further implied that the characteristics of each link, cargo- and equipment item, ship and vehicle in a path would be identified and documented, if necessary through a time and motion study and analysed with respect to compatibility of cargo, terminal equipment, vessel, the physical layout of / along the path, and manpower requirements, i.e. the number, skill and training requirements of staff. To this end the stochastic sequences of activities, facilities, cargo handling equipment, information and manpower constituting the port / terminal processes were reviewed and documented for a container terminal, a dry bulk cargo terminal and for a break bulk cargo terminal.

The TPB discussed above appears to concentrate on container terminals. This appearance is deceiving and equal attention has been given to Ro-Ro-, dry bulk- and break-bulk terminals. The extensively documented processes were peer reviewed by the industrial partners. A fabulous wealth of information and experience was made available by them and could be included in the documentation. Observing the flow of container handling vehicles on the container terminal in Cork led to the conclusion that there was no one-way system in operation on this terminal. The movements of straddle carriers in the container yard, on the apron and on the unloading and loading areas for articulated road vehicles near the gates were somewhat random. Cargo, cargo handling equipment, terminal staff and terminal layout were found to be in harmony and working well. A subsequent time and motion study on this terminal confirmed this.

The characteristics of links, cargoes (containers), equipment items, ships and land vehicles are stored in the object oriented relational database. The user enters or selects them. The TPB is generic. Its application as presented in this paper though was specific. This necessitated that each entity was considered individually. Object orientation demanded that each entity of the TPB is 'live', can be saved, edited and reloaded for subsequent work. This implies that each, e.g. line representing a path or a segment of a path, cargo item, piece of equipment or vehicle has to be stored together with its characteristics. The icons in the tool bar are not only pictures but objects. They are associated with the characteristics of the real life object they depict. Rather than use a fixed set of data for this, a facility for the user to enter this data, as befits the terminal under consideration, has been provided. The database has been designed to take account of this. The graphical user interfaces to enter characteristics of cargo handling equipment are demonstrated in Figure 6 and 7 below with respect to a straddle carrier and a 20 ft container.

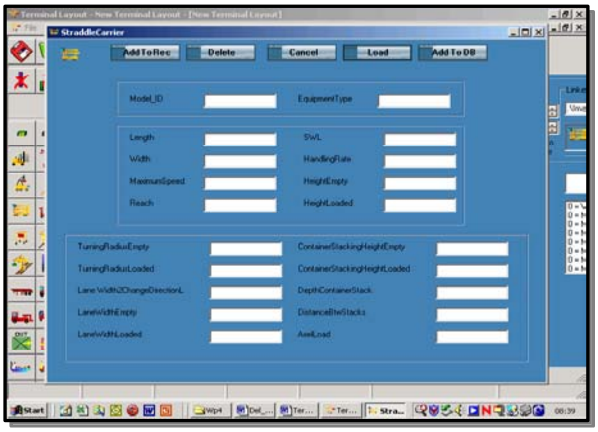

Figure 6: The GUI for Terminal specific Equipment

The Information required for Terminal Layout for 40 ft Containers (2 TEU Ground Slots) using Straddle Carriers is listed below and may serve as example.

- SWL 40 tonne
- Handling rate 20 / h
- Length 9.2 m
- Width 4.9 m
- Height empty 11.8 m
- Height loaded 11.8 m
- Container stacking height loaded 3
- Container stacking height empty 3
- Distance between stacks 2 m
- Depth of container stack (1 row) 2.5 m
- Turning radius loaded 10.5 m
- Turning radius empty 9.5 m
- Lane width to change direction
- – loaded 10.5 m
- Lane width – loaded 7.0 m
- Lane width – empty 7.0 m
- Axel load 24 tonne
- Maximum travelling speed laden 24 km/h

The same approach of combining TPB and database has been used to determine, enter and store the characteristics of terminal entities required for operational as well as layout planning. Figure 7 below illustrates this for containers.

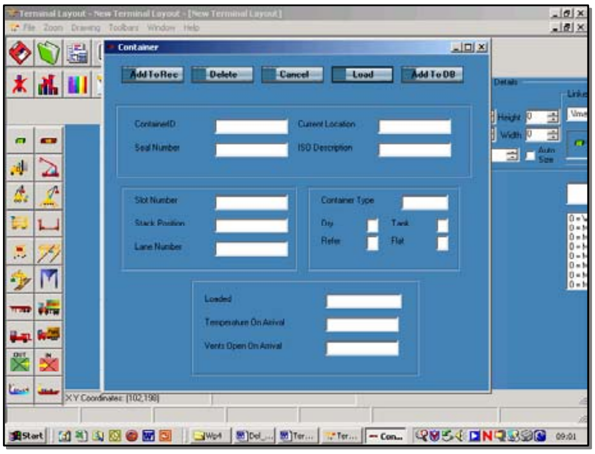

Figure 7: The Graphical User Interface for a 20-Foot Container

Slot number, stack position and lane number specify where on the terminal the container is stored. The information helps with tracking and tracing of the box. The same GUI as shown in Figure 7 above and the same comments made, apply to the 40 foot container. The arrangement of ground slots on the terminal is generally made in terms of "Twenty Foot Equivalent Units" (TEU) with two of these making up a ground slot required for a 40 ft box.

The information of all of the icons, together with that related to lines and nodes, once stored in the object oriented relational database constitute the data required for simulation.

After establishing and verifying the display and correctness of the "Status Quo" by means of peer reviews and terminal visits, and engaging in similar activities with respect to terminal processes and characteristics of, e.g. cargoes, cargo handling equipment and vehicles, the objective of WP4 demanded that: "The building blocks or entities of the TPB could be rearranged or changed within the confines of the plan view of the terminal and that options regarding the selection of cargo handling equipment, terminal vehicles, manpower requirements, terminal layout as well as information flows, could be explored with the aim to find not only a more efficient way of operating but also a better combination of terminal layout and operation". Figure 8 below gives an indication of this work.

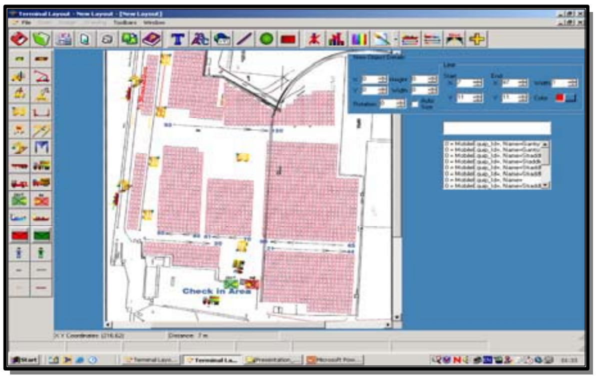

Figure 8: Phase I of the Development at the Tivoli Container Terminal, Cork

The Tivoli Container Terminal underwent considerable development and expansion during the two years of TRAPIST. This was done in two phases. Figures 8 above and Figure 9 below show these developments. They were produced in the same way as Figure 5 and demonstrate the capability of the TPB to take account of changes in terminal layout.

In all cases the TEU ground slots were aligned East-West and about parallel to the quay. This resulted in some access and congestion problems for straddle carriers in the North of the terminal. The solution was found by realigning the ground slots of this area North-South.

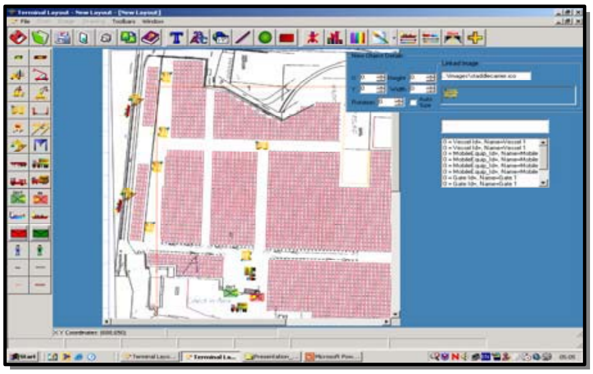

Figure 9: Phase II of the Development at the Tivoli Container Terminal, Cork

Figure 10 depicts this common sense solution to the layout problem of the latest development phase of 'Tivoli' without negatively affecting the terminal's capacity.

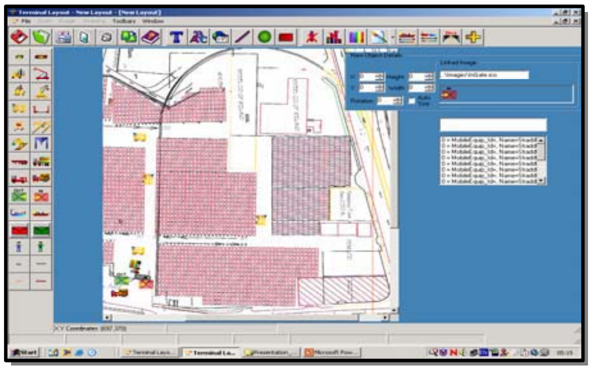

Figure 10: Alternate Layout of Ground Slots for the 2nd Development Phase of 'Tivoli'

With respect to the Port of Kokkola, the problem was related to a new road to be built to connect the 'General Port' with the 'Deep Port'. The old and existing road connection was too long, too narrow and had too many bends and was difficult to negotiate for the large and heavy vehicles transporting zinc ingots from the warehouses of the factory situated in the vicinity of the Deep Port to the General Port for loading into vessels bound for Amsterdam. Figure11 below shows the layout of this port and the connecting new road to be built, thereby halving the travelling distance.

The capability of the TPB to develop alternate layouts within the confines of an existing terminal layout was successfully tested and industrially applied by selecting two considerably different ports. The objective of WP4 of TRAPIST has been well achieved.

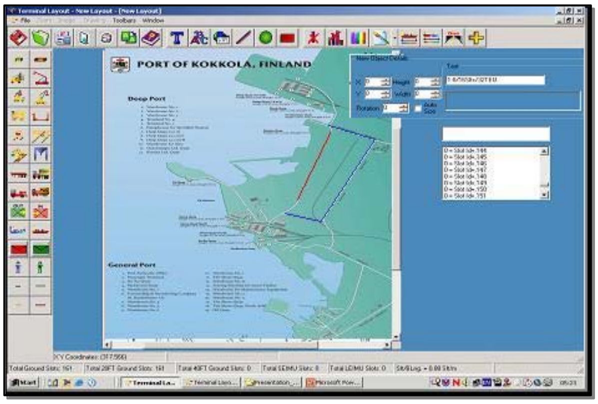

Figure 11: New Road (in red) connecting the General Port with the Deep Port

BENEFITS

These accrue to terminal and ship operators and to a similar extent to hauliers delivering and / or collecting containers to / from the terminal. Regarding exporters, importers and freight forwarders, an efficient port / terminal is a commercially attractive proposition and generates more business. Improving the efficiency of a container terminal, or of any other terminal for that matter, by increasing the cargo throughput, reduces the turn-a-round time of vessels and other vehicles as well as the unproductive times on the terminal. A benefit-cost analysis was carried out as part of Workpackage 6 of TRAPIST. It was concerned with "Optimal Loading / Discharging of Liner / Feeder Vessels" and based on information prepared by MARAN, NL. Benefits were estimated as 515 Euro for every hour gained for a 750 TEU vessel. With respect to a small to medium sized terminal and assuming operating expenses per year to be 6,180,000 Euro, assuming further a 52 week year, six days / week and 10 working hours per day, terminal / port benefit of 1980 Euro for every hour gained through increased terminal / port efficiency were estimated.

CONCLUSIONS

This paper puts the EU sponsored RTD work done in WP4 of TRAPIST into a European perspective. It examines critically the overall objectives and achievements of the WP. These are:

- An object oriented relational database and associated GUI, and
- A Terminal Planning Board.

It has been shown that the prototype system referred to as TPB in conjunction with the object oriented relational database is capable of displaying existing and alternative terminal layouts. It has been demonstrated that it can be used to depict the status quo and from this starting point develop alternate terminal layouts. The 'Tivoli' Container Terminal of the Port of Cork has been used for this purpose. Subsequently, the need expressed by the Port Authority of the Port of Kokkola for a new road connecting the general Port with the Deep Port was used to prove the applicability of the TPB to the planning of this task.

The combination of TPB and database enables:

- Re-engineering of terminal layout, selection of cargo handling equipment and working methods to reduce manpower, travelling distance and or -time by using different routes, equipment and arrangements of slot spaces to increase terminal capacity, terminal throughput and terminal efficiency.
- Making use of the 'common sense' approach by providing the terminal operator with a tool enabling him to translate his operational experience into the layout of slot spaces, positioning of gates, terminal access, and the selection of cargo handling equipment. Entities of the same equipment type but with different operating characteristics can be stored in the database and used.
- Populating the database with the terminal entities and their characteristics yields data for the simulation system, addresses access issues both for land and maritime access, superimposing and displaying the links over the map of the terminal enables network analysis, and last but not least, the operational characteristics entered into the database aid benchmarking.

In summary, the TPB affords:

- Potential planning opportunities
- Obtaining of real time information through the operational aspects of the TPB in association with gate procedures
- Operationally feasible results
- Helps maximising the use of existing facilities
- Supports the efficient layout of new facilities
- Is user friendly to industry
- Does not need extensive and specialised support of IT personnel.
- Forms a direct link to selected simulation programs.

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