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SIMULATION OF A NEW PORT-SHIP INTERFACE CONCEPT FOR INTER MODAL TRANSPORT.

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KEY WORDS

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ABSTRACT

This study is part of the project Improved Port/Ship interface (IPSI) , supported by the EU Commission. The general objective of the project is to strengthen the economic position of waterborne transport, especially short sea shipping. In the IPSI-concept, the terminal is the central point of inter modal logistic chains. This paper concerns a simulation study, with the overall objective to prove that the IPSI-terminal concept can work under realistic conditions. The innovative terminal concept allows horizontal loading and unloading of seagoing ships by Automatic Guided Vehicles [AGVs] , and is designed for fast throughput and short in-port times. The simulation shows that maximum capacity of the IPSI-terminal is 1.75 million twenty feet container equivalents (TEU) per year. Guidelines are derived for terminal design taking into consideration the terminal dimensions, cargo flow characteristics, equipment characteristics and desired service levels for all modes of transport

INTRODUCTION

Short sea shipping has a tremendous capacity available for transportation of goods between European harbors. This offers opportunities for transferring transport in Europe from land to sea. This however is only possible if the waterborne transport link is part of a complete multi modal logistic chain, which is competitive with other transport options with respect to economics and logistics. In such a logistic chain the efficiency of the cargo transfer between port and ship and the connection with land based transport modes is very important. In the project "Improved Port/Ship Interface" (IPSI) (Pederson et al. 1999) a new concept for flexible and efficient interfaces between land- and waterborne means of transport has been developed. Several aspects of the concept have been studied in the IPSI project such as: new concepts of fast and cheap unloading and loading of vessels, terminal equipment design, port design, ship design and terminal logistics.

THE IPSI TERMINAL CONCEPT

The novelty of the IPSI idea is to load and unload vessels using automated guided vehicles (AGVs).

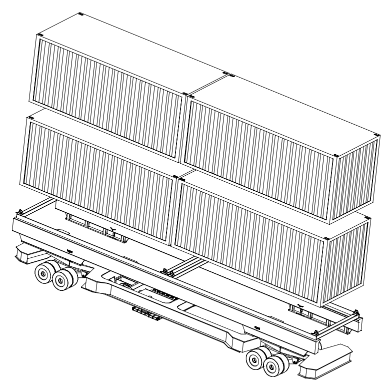

Figure 1: the IPSI load concept. The cassette or frame may carry four TEU. The AGV can drive underneath the frame and lift it up.

For example in case of loading a ship, an AGV picks up the load at shore, drives onto the ship, puts the load down and drives back to shore for the next move. This principle is comparable with traditional roll on roll off systems which however need manned trucks to do the job.

The Load Unit.
As a load unit the so called cassette system is used, which is well known in the Scandinavian countries.
Figure 1 shows a cassette or frame which can be loaded with 4 twenty feet equivalent containers (TEU), that means four 20 feet or two 40 feet maritime containers. An AGV is able to drive underneath a frame, lift it up, transport it and put it down again. The gain in (un)loading speed is obtained by entering the ship with "AGV trains". The train formation happens dynamically and the coupling of the vehicles is virtual (no physical connection). The frames are pre-positioned in lanes on the so called Marshalling Area.

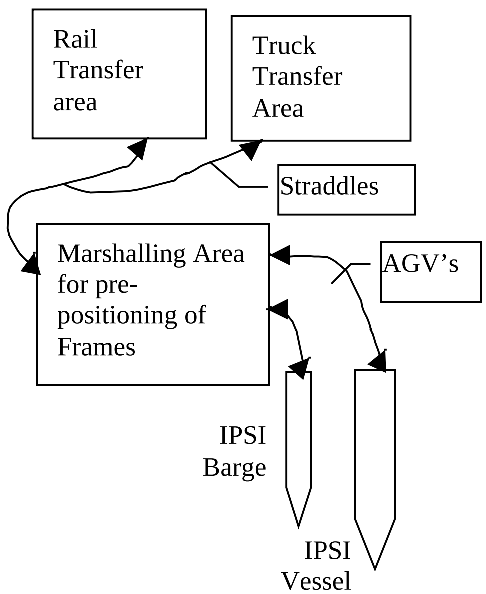

Figure 2: Schematic lay out of the IPSI terminal

During the IPSI project simulation was applied for two purposes and consequently two models are made.

1. Determine the logistic performance of the systems and gain insight into dimensions of capacity needed and sensitivity of the concept for different land side arrival patterns and IPSI vessel arrival cycles. The model developed is called the IPSI *Flow Model*.
2. Prove the feasibility of the AGV –concept, included the development and testing of the AGV control system. This model is called the IPSI *Terminal Model* which is described in the ESS99 paper of H. Veeke: "Detailed Simulation of the container flows for the IPSI-concept" .

In this paper the IPSI *Flow Model* is covered. In this model the results of the *Terminal Model* are applied.

GOALS OF THE SIMULATION STUDY

The first goal of the simulation study with the flow model is to determine for several IPSI vessel arrival cycles the amount of equipment needed for operating the IPSI terminal for well defined demands and service levels at both sea side and land side. Two types of equipment are included: the automatic guided vehicles (AGVs) for loading and unloading both IPSI vessel and IPSI barge and the manned equipment which is used to load and unload trucks, trains and IPSI frames. These carriers might be "straddle carriers" or any equipment type which is capable for the loading and unloading task. In the paper they will be referred to as 'straddles'. The second goal is to indicate the space needed for the IPSI terminal. This will be expressed in terms of numbers of containers and IPSI frames which have to be stacked in the terminal area. The results of this study have been used for the cost calculations of the concept.

PERFORMANCE DEMANDS

An IPSI vessel is supposed to carry 400 TEU both import and export cargo. The main demand on sea side is that the IPSI vessel has to be unloaded and loaded within 2 hours. As the IPSI terminal is supposed to be a link in a well controlled multi modal transport chain, it is demanded that all export cargo which is provided will be loaded onto the first IPSI vessel arriving. The import cargo from an IPSI vessel should be handled and processed to inland modes before departure of the next IPSI vessel. This puts high demands on the IPSI terminal operations but also on the providers on land side. It is assumed in this study that the land side export and import streams are according some well defined arrival patterns. On land side three modalities are included:

- Barges for inland shipping. Only so called IPSI barges are considered. An IPSI barge only carries frames and will be handled exclusively by the AGV system. It is demanded that the unload and load operations on barges will be completed between two IPSI vessel calls.
- Trains for the rail modality. It is demanded that all export rail containers are unloaded from the train and loaded onto the first IPSI vessel and that all import containers from an IPSI ship are loaded onto a train before next IPSI departure.
- Trucks for the road modality. As trucks are manned this modality demands a high service level. Planning of truck arrivals is much more difficult than train and barge, so a certain deviation in arrival times and even peaks in arrivals will be unavoidable. Therefore some different arrival patterns are investigated. For truck service it is demanded that 90% of the trucks will be handled within 15 minutes for both export and import cargo. This is called the 90% percentile.

MODELING

The process interaction modeling technique was used in combination with an appropriate object oriented software package (Robert, C.A., Dessouky, M. 1998). In this approach the dynamic system elements are modeled as parallel processes which may have mutual interactions. It provides a very natural way of modeling and is flexible with respect to adjusting the model with growing insight. In this case a PASCAL oriented software package (MUST '92; Veeke and Ottjes, '99) was applied. In the course of the IPSI project several terminal arrangements have been considered and modeled. Only the final one will be reported here: the IPSI terminal, shown schematically in figure 2.

Model Parameters

In the model several parameters are incorporated. These parameters are varied systematically in the simulation runs in order to measure the response of the system. They can be divided in the following parameter groups:

1. *The terminal lay out: location and dimensions of stacks, rail tracks, docks and IPSI vessels. multipliers for terminal distances for easy varying terminal dimensions.*
2. *Equipment : Number of AGVs, number of Straddle carriers, equipment characteristics: speed, acceleration and deceleration, positioning times and picking and placing times.*
3. *Cargo flow characteristics: IPSI vessel cycle time, in port time, number of frames import and export, TEU factor import and export, modal split (percentages truck, train and barge for import and export), frame utilization, import and export arrival patterns of trucks.*
4. *Control variables, defining handling priorities depending on the state of the system. For example if an IPSI vessel is present and the export marshalling area is not fully filled yet , straddles will give priority to loading the marshalling area above handling trucks and trains with import containers.*

Every simulation run with the flow model demands a combination of the above mentioned parameters as an input. We call one combination an input set.

Performance Indicators

The performance of the system is measured as a function of several input sets. Based on the performance indicators it is decided if a specific input set is feasible. The main performance indicators are:

- *Completion time of the IPSI vessel.*
- *Completion time of the IPSI barge. The barge should be unloaded and loaded in the time between two IPSI calls.*
- *Completion time of trains.*
- *Truck service measured as the 90% percentile of the truck waiting times.*
- *Average occupation rates of AGVs and Straddles.*
- *Average cycle times of AGVs and Straddles*
- *Average lengths of AGV and Straddle trips.*
- *Maximum number of frames in the marshalling area, indicating stacking space needed.*
- *The occupation rates of straddles and AGVs as a function of time giving peak demands in the system*
- *Queue lengths of waiting trucks indicating parking space needed*

EXPERIMENTAL APPROACH

One of the findings of the Terminal Model was that the number of AGVs needed is 20 (two trains of 10 AGVs) and this number is invariant with respect to the other parameters. Based on preliminary cost calculations a case was designed and thoroughly investigated. This so called *central case* was based on a terminal operation point with a fixed modal split, frame utilization and TEU factor.

Three types of simulation experiments were performed:

1. Determining the performance of an IPSI terminal for the central case by varying the IPSI cycle time and the number of straddles deployed.
2. Performing a sensitivity analysis for al model parameters by varying these values around the central case values.
3. Determining the maximum capacity of the IPSI terminal under extreme load conditions.

The Central Case

The average frame utilization was assumed to be 75% and the TEU factors for both import and export stream were taken 1.7. Table 1 gives the flow data. Every IPSI ship delivers 100 frames and takes another 100 frames. Every frame has a capacity of 4 TEU, which means 800 TEU import + export for one vessel. For three arrivals per day this means a maximum of 2400 TEU. 75% of this gives the 1800 TEU of table 1. The TEU factor of 1.7 means that for example the 440 truck TEUs consist of 440/1.7= 259 containers or 'units' as in table 1 is indicated. It was determined that values to be measured in a simulation run were stable after a run of one week. Therefore a simulation run length of one week was chosen for all experiments.

In this investigation it is assumed that the IPSI barge only contains cargo for the next IPSI vessel and receives cargo from the last IPSI vessel. Consequently the barge stream does not require straddle carrier capacity This is the big advantage of the IPSI barge concept.

Table 1: cargo flows of the central case for 24 hours based on an 8 hours IPSI cycle. The average frame utilization is assumed to be 75% and the TEU factor is 1.7

	Truck		Train		barge		Total
	TEU	Units	TEU	Units	TEU	Units	TEU
containers	440	259	560	329	800	471	1800
trailers	360	180	240	120			600
total	800	439	800	449	800	471	2400

Sensitivity Analysis
In the model several stochastic influences are modeled: The composition of each frame taking into account the frame utilization and the TEU factors, the equipment handling times, the equipment travel times and the truck arrival times. These stochastic influences cause a certain deviation in the simulation results. It appears that these deviations are not significantly influencing the straddle carriers requirements if a run length of one week is applied. Other parameters however such as for example the frame utilization factor, which have been assumed to be constant in one simulation series, may in reality vary from ship to ship. This may cause deviations in requirements of terminal capacity too, especially if the number of straddle moves varies. Therefore a sensitivity analysis has been performed around the central case. The parameters varied in the sensitivity analysis are: frame utilization, TEU factor, truck arrival patterns, terminal dimensions and modal split : barge, truck and rail fraction.

Maximum Capacity
In order to determine the upper level of capacity of the IPSI terminal, series of runs are performed under extreme terminal load of 100% frame utilization and no barge frames. The latter means that all containers are to be handled by the straddle carriers.

SIMULATION RESULTS

In figure 3 the results are shown of five series of experiments varying the cycle times of IPSI vessel arrivals from 12 hours down to 3 hours.

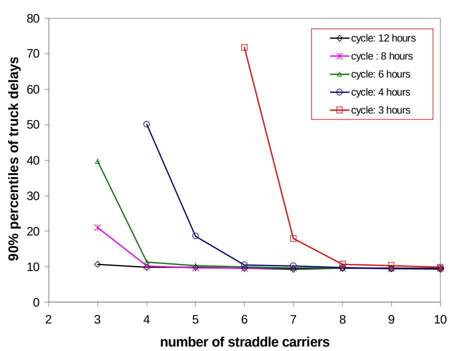

Figure 3: 90% percentiles of truck delays for 3,4,6 and 8 hours IPSI ship cycle.

The data point on the graphs of figure 3 are obtained by studying the truck waiting time distributions as shown in figure 4. Apart from the service demands on truck waiting times the rail modality should be served properly. That means that train handling should be completed within one IPSI cycle. Figure 5 shows the train load as a function of time.

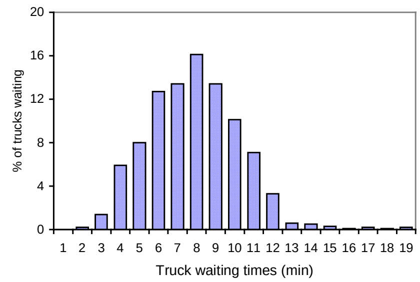

Figure 4: typical truck waiting time distribution

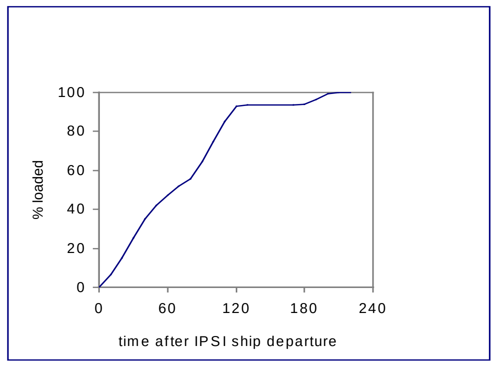

Figure 5: Cumulative train load with import containers in the central case for a four hor IPSI cycle.

The flows were according the central case. It should be noticed that the AGV system is modeled in a simple way so the results only give an indication. The specific AGV data are obtained from the terminal model.

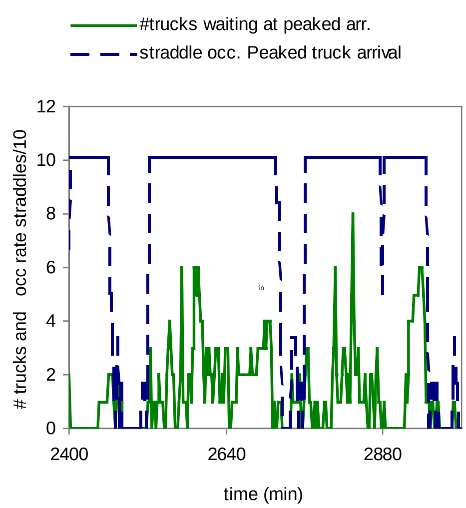

Figure 6. Typical patterns of number of trucks waiting to be handled and straddle occupation.

Figure 6 gives the number of trucks waiting and the straddle occupation as a function of time. Only a short time period is shown but the shape of the curves is typical. Figure 7 shows the simulation results under extreme terminal load conditions. It appears that a throughput of 4800 TEU per 24 hours is feasible when 11 Straddles are employed.

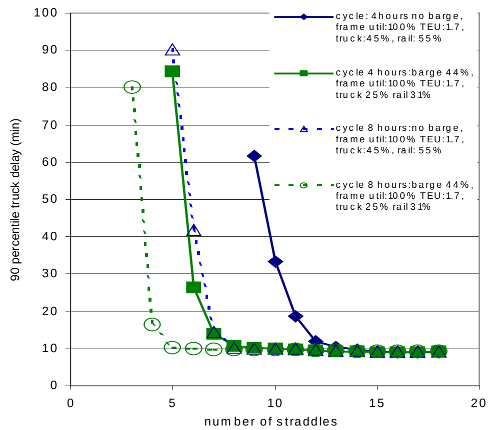

Figure 7: 90% percentile truck delay vs. number of straddles for IPSI cycle 4 and 8 hours under extreme terminal load conditions

CONCLUSIONS

- Determination of The Number Of Straddles.

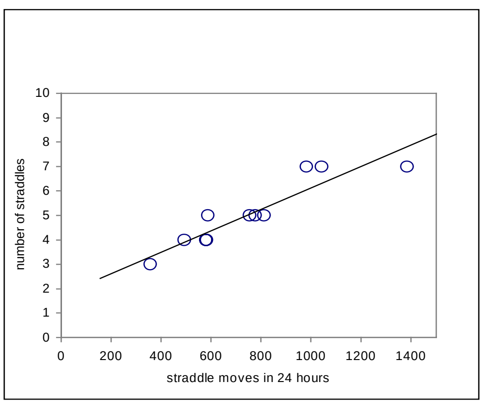

Figure 8. Number of straddles as a function of the number of straddle moves per 24 hour for IPSI cycle 8 hours.

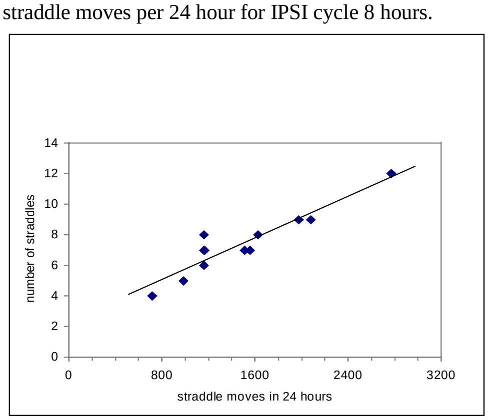

Figure 9. Number of straddles as a function of the number of straddle moves per 24 hour for IPSI cycle 4 hours.

Figure 8 and 9 show the relationship between the number of straddles and the number of straddle moves for an IPSI cycle of 8 and 4 hours respectively. In all cases the performance demand listed before were met. In order to determine the equipment needed for some IPSI configuration the net number of straddle moves in 24 hours has to be calculated. Then figures 8 or 9 may be used for determination of the required number of straddles. For cost calculation purposes a number of 11 straddles have been taken. This can be considered to be a rather conservative estimate.

- An IPSI terminal with a cycle time of four hours is feasible with respect to land side and sea side handling. This implies a maximum flow of 4800 TEU per 24 hours or 1.75 million TEU per year.
- The number of frame positions needed at the marshalling area is 200, so a complete import and export batch for an IPSI ship. This is logical because all cargo of an IPSI ship has to be processed in one IPSI cycle.
- The influence of arrival patterns of trucks on equipment requirements appears to be considerable. Therefore it is necessary that the IPSI terminal is part of a well controlled logistic chain and that it is possible to control the land side arrival patterns to minimize the need for land side handling equipment. Further research on this issue is required.
- Train batches can well be handled within one IPSI arrival cycle.

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SAGA S.A. (Fr)
Jebsen Wilson Eurocarriers (No)
Sintef production engineering (No)
Norwegian Marine Technology Research institute (No)
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