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A SIMULATION MODEL OF A SAILING CONTAINER TERMINAL SERVICE IN THE PORT OF ROTTERDAM

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ABSTRACT.

This paper examines the structure, operation, required input data and the output of a simulation model that is used for a simulation investigation for a Sailing Container Terminal (SCT) for the port of Rotterdam. The SCT will be used to tranship small consignments of containers between the inland waterway and feeder vessels and the shore based container terminals of the port of Rotterdam. The objective is to reduce the turnaround time of the vessels and to increase the efficiency of the transhipment of the containers themselves. In addition the SCT will be used to transport containers between the various terminals, in other words for Inter-Terminal Transport (ITT). The model is generic with respect to the following features: All necessary shipping lines, each with characteristic container flows, origin and destination distributions can be defined. All shore based terminals involved can be defined, each with a set of container cranes, inter-terminal flow characteristics, opening regimes and geographic data. A choice can be made from all types of rendezvous and operation strategies of the SCT. Experiments with the model indicated that under certain conditions, an SCT service system is feasible in the Port of Rotterdam.

INTRODUCTION.

The Port of Rotterdam handles large streams of containers via deep sea shipment originating from all over the world. The container flow to and from the hinterland of Rotterdam proceeds via road rail and water. A considerable volume of container traffic is carried on the inland waterways, a major stream moving to Germany along the Rhine. The containers destined for or originating from other European harbours are distributed by small sea-going vessels, called feeders. Several shipping lines are involved in container transportation to and from approximately 25 container terminals in the Rotterdam area.

Figure 1 shows schematically the locations of some clusters of container terminals in the Port of Rotterdam.

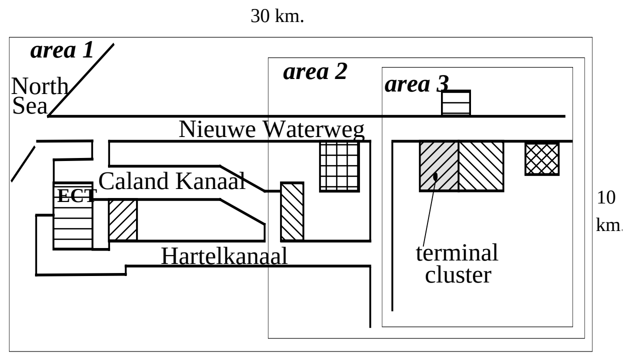

Figure 1: Schematic view of the Port of Rotterdam. Segmentation into three possible operational areas of the SCT is indicated. Each area contains several terminal clusters.

A vessel may carry containers from various terminal destinations and/or has to collect containers from various origins. A group of containers with the same destination terminal or terminal of origin is defined as a consignment. So one ship may carry several consignments. Incoming ships loaded with several container consignments, each with a different destination terminal, have to distribute their loads over these terminals. Outgoing ships have to collect their container consignments from various terminals.

From the available statistics it appears that, on average, an inland shipping vessel visits 10 terminals, a round trip takes some 32 hours and half of the consignments consists of less than 6 containers. Moreover the variations in round trip duration are large and consequently these round trips are difficult to plan.

Another consideration is the inter-terminal container transport. There is an intensive interchange of containers between the terminals. This ITT flow is currently achieved by barges or by truck transport over roads which tend to be increasingly congested.

The idea which led to the development of an SCT as a connecting link between ships and onshore terminals and between the terminals themselves, derives from the need to reduce duration of round trips for ships and provide more reliable sailing schedules and to reduce inter-terminal road transport.

THE CONCEPT

The SCT consists of a self propelled floating platform, equipped with one or more container cranes. It will make regular round trips, visiting all shore based terminals to exchange containers.

The mode of operation of the SCT is planned as follows:
Every 24 hours the SCT moves round the terminals in the harbour area and distributes and collects small consignments. Ships rendezvous with the SCT at a dynamically determined location somewhere on the route or at a fixed meeting point. At this fixed meeting point the SCT is at anchor for some time after each round trip. Contact between ships and the SCT must have been established before, during or right after the round trip of the ships during which they exchange their large consignment with the destination terminals.

Topics which have to be investigated include:

- The dimensions of the SCT, including container stack capacity on board, speed, number and characteristics of the cranes. (internal SCT logistics)
- The maximum number of containers forming a "small " consignment to be handled by the SCT.
- Schedules and routing of the SCT.
- Rendezvous strategies: static and dynamic.
- The influence of the number of terminals which utilise the SCT facility.
- The area in which the SCT is operating

Main performance indicators are turnaround times of ships and SCT, waiting times of ships and SCT and the maximum number of containers which can be handled by the system

The total project is supervised by a project group consisting of representatives of the Rotterdam Port Authority, terminal operators, shipping-line operators and the Delft University of Technology. The project is co-ordinated by the Rotterdam Internal Logistics (RIL) organisation (Thomas, 1993)

THE MODEL

The process oriented approach was used to construct the model (Zeigler, 1976): the system is broken down into logical component classes each of which has typical attributes forming a data structure.

Two types of component classes are distinguished: data component classes, which carry only their data structure and "living" component classes, which have their data structure and their typical behaviour in the system. This behaviour is dynamic and is called the process of the class. All components of a class comply with the process description of that class. The components act concurrently; they may interrupt or activate each other. The method fits well to the real system, although, it is difficult to give a formal model description of the system dynamics. Here the informal technique of pseudo-coding will be used to illustrate the model. Use of the pseudo-code makes possible the description of the dynamic parts of the model: the processes of the "living" components. The pseudo-code shows what happens rather than how it happens.

A crucial element is the inclusion of time consuming statements in a process description. A time consuming statement "consumes" system time e.g. the process in which it appears may temporarily be interrupted. Time consuming statements in pseudo-code are: *hold* (a certain time), *passivate* (wait for reactivating by another component) and *wait until* or *wait while* (wait for a state event). A component which is passivated may be restarted by the command *reactivate.* A component which is suspended by a hold command may be prematurely interrupted by another component with the command *cancel.*

The informal model description in pseudo-code is legible to the client and can be discussed in detail. When a consensus has been reached the informal model has to be translated into formal computer code. This is relatively easy if a process oriented simulation language is used. In this case the modelling is carried out with the simulation package "Must" (Upward Systems, 1992) and object oriented Borland Pascal 7.0. With the Must package, in addition to the availability of a large number of simulation utilities, concurrent processes may be defined. Component classes are modelled as objects and their processes as the object methods. The Must package has been extensively used in the design of large container terminals especially when complex control strategies are concerned (van der Ham, 1990)

Figure 2 shows the system modelled. Apart from the SCT, the terminals play an important role in the model. Even terminals which do not utilise the SCT system have to be modelled because of their influence on the system performance. Ships may have cargo for these terminals and must of necessity deliver and collect all consignments themselves at these terminals.

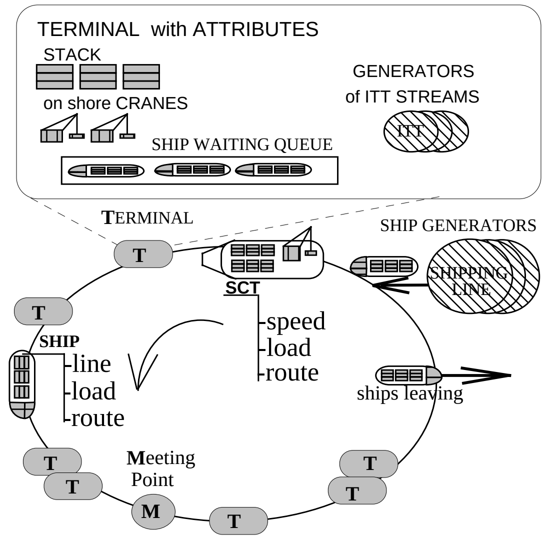

Figure 2: schematic view of the model structure.

The main component classes of the model are: SCT, SHIP, SHIPPING LINE, TERMINAL, CRANE, CLOCK and CONSIGNMENT. Here a condensed version the informal model description will be given:

CLASS: SHIPPING LINE
attributes
-Name and line number
-Maximum number of containers to form a "small consignment"
-Distribution of ship arrivals per week
-Relative distribution of ship arrivals over certain periods. Here 21 shifts of 8 hours completing a week are used because there appeared to be an arrival periodicity of one week.
-Distribution of inter-arrival times of ships per period.
-Distribution of number of containers per ship.
-Distribution of destinations of the container consignments on board
-Distribution of the origin terminals of container consignments to be loaded

PROCESS OF A SHIPPING LINE
Generate ships and their relevant attributes according to the line specifications.

CLASS: CONSIGNMENT
attributes
- Number of containers
- Line number
- Arrival time
- Due time of delivery
- Destination (terminal or ship)
NO PROCESS

CLASS: CRANE (of on shore terminal)
attributes
- Move rate characteristics. (depends on consignment size)
- Reference to own terminal
CRANE PROCESS
While there are ships in ship waiting queue of your terminal do
-Select ship from ship waiting queue (this may be a ship or the SCT if the SCT is not allowed to use its own crane)
-Hold handling time of the ship (unloading and/or loading of the relevant consignments)
-Reactivate the ship.
Passivate
Repeat the process

CLASS: SHIP
attributes:
-pre-arrival time (between reporting and real arrival)
-Line (ship line it belongs to)
-Load composition (consignments to deliver to terminals and to collect for the return voyage)
-Route along the terminals (is determined dynamically)

PROCESS OF A SHIP
Report arrival ·
Read loading data and create all consignments to be delivered and to be collected at the terminals or via the SCT.
Hold pre-arrival time
While there are terminals or SCT to visit do
-select next terminal to visit; (for example: prefer terminals with restricted opening periods, take into account cumulative workload of the terminal, choose then terminal with shortest distance).
-hold sailing time to this terminal
-report to terminal and enter the ship waiting queue of the terminal and activate a crane if one is free.
-passivate (wait for treatment by terminal or SCT)
Disappear from the system

CLASS: TERMINAL
attributes:
- Geographic information
- Opening regime
- Stack for small consignments for hinterland (via SCT)
- Stack for large consignments for hinterland (directly to ships)
- Stack for inter terminal consignments. (via SCT)
- Ship waiting queue
- Set of cranes
- Number of ITT streams
-The inter arrival and destination distributions for each ITT stream

TERMINAL PROCESS
Generate ITT container consignments according to the specifications

CLASS: SCT (Sailing Container Terminal)
attributes
- Sailing speed
- Load composition
- Route along the terminals (is determined dynamically)
- Move rate characteristic of crane.

SCT PROCESS
(there are two sub processes: make round-trip and handle ships at fixed meeting point)

sub process: Make round-trip
While there are terminals to visit and schedule allows do:
-Hold sailing time to next terminal
-If use of own crane is not allowed then enter the ship waiting queue of the terminal and passivate
Else exchange container consignments using own crane
-If ready at the terminal then look for a ship to exchange consignments with (depending on strategy) and handle it, whitch implies:Hold handling time of the ship (unloading and/or loading of the small consignments with SCT crane) and reactivate it.
End of sub process round trip
Proceed with sub process handle ships at fixed meeting point.

sub process: Handle ships at fixed meeting point
Open meeting point according current strategy
While meeting point open do
-Wait until there are ships to handle in the ship waiting queue of the meeting point
-Take first ship out of ship waiting queue of fixed meeting point and handle it, which implies: Hold handling time of the ship (unloading and/or loading of the small consignments with SCT crane) and reactivate it.
End of sub process Handle ships at meeting point
Proceed with sub process round trip

THE MODEL INPUT.

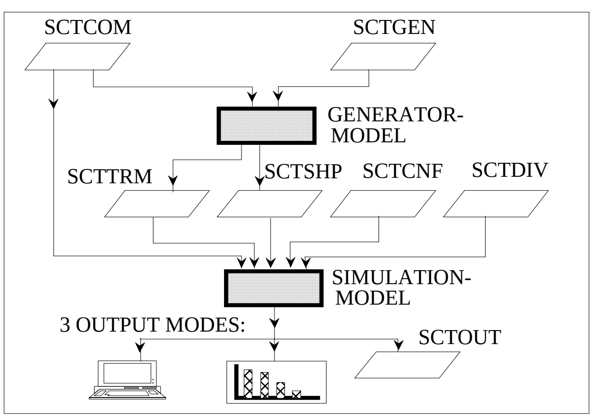

Figure 3: Models and file structure.

Figure 3 shows the file structure of the simulation model. This structure will be followed to illustrate the input files.

The input data of the model consist of configuration data and container flow data. In order to obtain relevant container flow data for the model a questionnaire was sent to inland shipping lines and the companies operating terminals. The questions concerned the extent of the container flow, the distributions in time and origin and destination of the containers. The data obtained were put in the file SCTGEN, which consists mainly of statistical distributions. A separate program, the generator model, was built to process the data of file SCTGEN to obtain relevant container input streams for the simulation model. The file SCTCOM contains the identities of the terminals and the shipping lines involved. These data are necessary for both the generator model and the simulation model. The generator model generates two files: SCTTRM, containing a list of consignments for inter- terminal transportation and SCTSHP, a list of ships with data about the consignments they are carrying and those they have to collect. In both files all relevant information is given including arrival time, terminal references and consignment size. These two files contain the consignment stream which has to be handled by the system. The file SCTCNF contains further information about the total configuration including switches for the control strategies; detailed data per terminal; geographical information; opening time regime; crane speed and load strategies; speeds of the ships and the relevant SCT data such as a crane characteristic and sailing speed. The file SCTDIV contains the distance table and the opening-time table of the system.

THE MODEL OUTPUT

The output of the model consists of a screen animation that shows the state of the system dynamically, a track and trace facility for ships and terminals, a menu controlled output facility, by means of which all statistical data can be inspected and recorded and a bulk output file, SCTOUT, in which all events and changes of state are recorded. This file is used in conjunction with a data base package to get supplementary information.

VALIDATION AND EXPERIMENTS

The model was validated in three ways:
1. Structural validation: The structure of the model and the dynamics of the processes were developed in close co-operation with practical experts of the supervising project group and approved.
2. The current situation (without the SCT) was simulated with the model. The experiments showed an average ship turnaround time which was very close (within 3%) to the time derived from the questionnaire mentioned.
3. The results of a typical simulation run with the SCT operating was printed out at event level, showing all detailed actions and decisions which have been taken in

the system. This material was studied by experts of the supervising project group and found to be realistic.

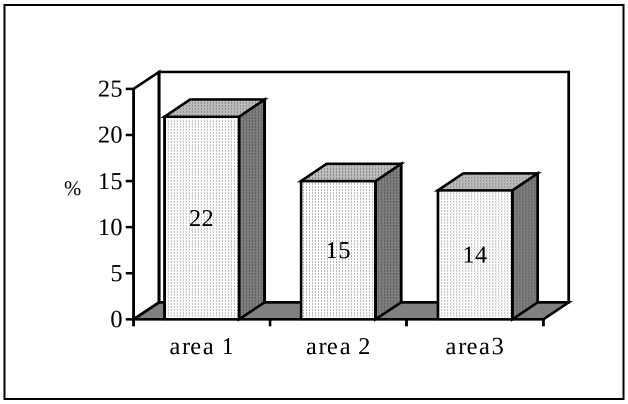

Figure 4: Reduction of average ship turnaround time with the SCT system operating compared to the existing practise without SCT.

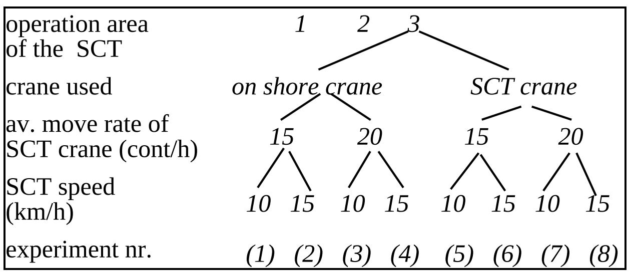

Figure 5: experimental set up for determination of the maximum container flow in area 3.

A large number of experiments were carried out, varying all model factors. To illustrate this, figure 4 shows, the reduction in ship turnaround times as a function of the area (fig. 1) in which the SCT operates, for a basic set of factors. It is obvious that the more terminals are included in the SCT system the greater the possible reduction of ship turnaround time will be. However, if the area is large the "sailing time" of the SCT will increase and consequently the number of containers which may be processed will decrease. For each area considered, the influence of all factors on the productivity is determined. Figure 5 shows an experimental set up for area 3 while varying 3 factors at 2 levels: The use of the SCT crane for moving containers to and from shore based terminals, the average move rate (containers/hour) of the SCT crane and the sailing speed of the SCT. In figure 6 the maximum production of the SCT (containers/year) is shown for the eight experiments.

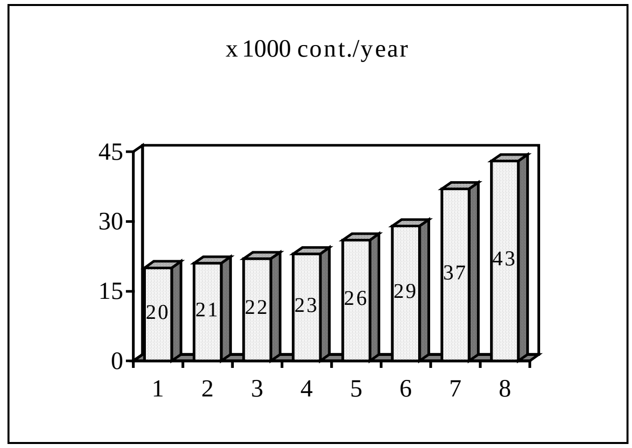

Figure 6: Maximum production of the SCT (containers/year) for experiments 1.. 8, defined in fig. 5.

CONCLUSIONS

Simulation appears to be a very useful supporting tool for feasibility and design studies of the sailing container terminal service. From the validation it was concluded that the simulation model provides an adequate representation of the real system. Several possible ways of operations were simulated and reported. From the experiments it was concluded that in the Port of Rotterdam an SCT service is feasible as far as the logistic performances are concerned. Several design data for the SCT were obtained from the simulation experiments, such as SCT dimensions, stack capacity and demanded crane capacity. Of the operational areas considered, area 3, the smallest, appears to be most suitable for the operation of an SCT. The next step, which is currently in progress, is to investigate the economic feasibility and the financing. It is assumed that the final decision on realisation will be taken during the course of 1994.

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