# Dynamic Modelling to Support Organizational Decision Making.
## *The Stevedore Case*


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***Abstract***

This paper addresses a simulation study that has been carried out in the Rotterdam Port to assess the value of decision alternatives for terminal entrance facilities and procedures. The organizations involved in this project are dynamic systems by nature, so a static analysis and design technique does not suffice when supporting decision processes. The Dynamic Modelling approach was therefore applied in a case study.


## 1 A problem in the port of Rotterdam

The Rotterdam-based company Europe Combined Terminals (ECT) is one of the largest stevedores in the world. It takes care of the stowage of about 15.000 ocean vessels every year, which are loaded with 250.000 containers, 100.000 cars, 200.000 ton of forest products and 30 million tons of so-called customized cargo. In that respect, ECT acts as a gate to the European market.

ECT operates 7 terminals in the port of Rotterdam. The largest terminal is called the "Eemhaven terminal", which is the focus of this paper. Trucks enter the Eemhaven Terminal to pick up cargo that has been brought in by ocean vessels (the import of cargo) or to deliver cargo that will be transported overseas by these vessels (the export of cargo). Of course, all kinds of combinations are possible. Furthermore, it should be noted that cargo trains and barges take care of about 20% of the total cargo flow. In this study, we have restricted ourselves to the 80% of the cargo that is dealt with by trucks.

The Eemhaven Terminal is depicted in figure 1. The terminal has three entrance gates, where 850 container carriers and 350 conventional trucks enter the terminal every day. The 850 container carriers first have to pay a visit to the so-called control terminal, which is located about three kilometers away from the Eemhaven Terminal. On this control terminal, the administrative procedures take place. As an example, we will briefly describe the procedures that have to be carried out when a truck driver wants to deliver a container for export to a non-EC country. The driver parks his truck at the control terminal and hands over the container documents to an ECT desk employee. The documents state the final destination of the container, the contents of the container and the ocean vessel the container has to be stowed into. The container is booked into the in-house computer system of ECT and a terminal stack position is assigned to it. The customs documents for export are filled out, and handed over to the customs officer at the control terminal, who stamps them to approve for export. The driver gets a copy of the documents and a little note stating the entrance he has to take and the stack position of the container. He or she then walks back to the truck and drives over public road to the Eemhaven Terminal. There the container is unloaded and stacked at the right position on the shore, waiting to be stowed.

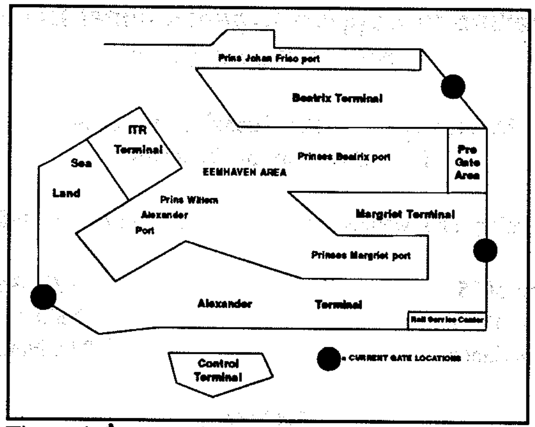


Figure 1: Layout of the 'Eemhaven' terminal area

It is the administrative process at the control terminal that concerns ECT management for two reasons:

- The control terminal procedure causes a significant delay for the truck drivers. On peak hours the waiting time can be up to two hours. Average waiting times are around 40 minutes.

- At the moment, the customs officers allow the trucks to drive from the control terminal to the Eemhaven Terminal over public road, although they are already approved for export. This will probably change in the future, when the EC regulations require a stronger rule enforcement at the borders of the European community.

In the near future there will be an opportunity to redesign the terminal layout and the administrative processes connected to the physical handling of cargo. About one third of the current terminal capacity is used by one large customer of ECT. The stowage operations for this customer will move to a newly built terminal elsewhere in the port by 1993. ECT management plans to redesign the terminal to overcome the problems mentioned above. The most important aspect is the implementation of a central gate where all in- and outgoing traffic passes through and where all administrative and security procedures are carried out. The plan looks globally as follows:

- The implementation of infrastructural changes that give direct access from the highway to the terminal. To support this, the municipality of Rotterdam has started to build a fly-over (crossing busy train tracks) to give better access to the terminals.

- The construction of a customs office close to the central entrance.

- The construction of ECT administration desks next to the central entrance. This requires the filling of a small part of the harbor. This might also involve the implementation of new procedures and information systems for handling containers and customized cargo.

- A reduction of the administrative procedures by means of inter-organizational information technology, in particular the use of fax messages as pre-arrival notices and the use of EDI. (EDI: Electronic Data Interchange, the computer to computer communication of business documents (see Streng et al. (1992)).

The investments that are necessary to carry out this plan are rather high. Furthermore, there is the risk that a central gate cannot handle the peak loads in traffic and will cause severe congestion on one of the most busy highways of the Netherlands. Therefore, the question is if the proposed project indeed solves the problems sketched above and if it will do so in a satisfying way.

An ECT project team was formed to answer this question. The problem situation is characterized by a high level of complexity. There are a number of independent organizations involved (ECT, customs, trucking-companies, forwarders, shipping-lines) that each have their own characteristics. The inter-arrival and handling time of the trucks are non-deterministic and can only be analyzed on a statistical basis. The problem situation itself has a close relationship with the dynamics of the primary process of ECT. These dynamics are essential to the problem and therefore a static approach to the question will not provide the answers that are needed.

For this reason, ECT has started a research project where it was investigated if the dynamic modelling approach that is under development at Delft University of Technology (the "LANE"-approach, see Streng and Sol (1992)) could be used to answer the following question:

*"Is a central entrance gate a good solution to the problem and is it possible to operate this gate in an effective and efficient manner?"*

## 2 A problem solving approach

In our case study, we use the problem solving cycle as described by Mitroff et al. (1974). Although it is criticized for modelling the problem solving process too much as a rational activity with clear milestones, we emphasize that we view it as an approach that strongly encourages the use of multiple iterations and that can be used in solving ill-structured problems. Sol (1982) has elaborated on Mitroff's process of problem solving, among other things by defining more concisely the terms "Specification" and "Solution Finding". The cycle is depicted in figure 2.

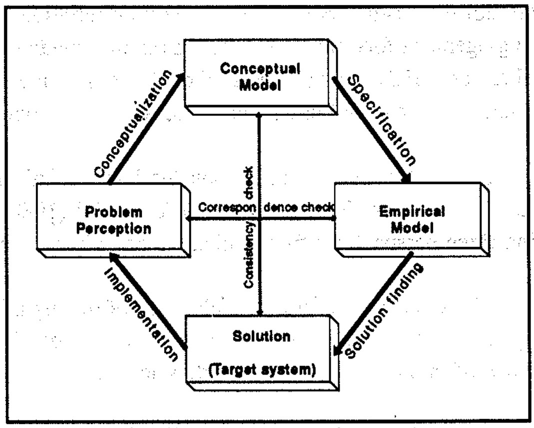


Figure 2: Mitroff's problem solving cycle

When the owner of a problem is realizing his problem, the cycle starts at the perception stage. The first thing that he or she will do is trying to formulate the problem by using concepts that he is familiar with. This gives him the vocabulary to describe the problem situation in detail and discuss it with other people. This detailed description is called the empirical model and the activity to obtain it is called specification.

The empirical model contains the problem situation as the problem owner sees it. Based on this model he or she will try to find possible solutions. Because we want to be explicit on the distinction between design and choice (see Simon (1947)), we have subdivided the activity "Solution Finding" into two activities: "Solution Finding", defined as the generation of a number of possible courses of action, and "Solution Assessment", defined as the activity that leads to a qualification of the various proposed courses of action and the choice for the preferred one.

The solution that comes out best in the empirical model can be implemented in reality if the problem owner views it as a satisfying solution. When the implementation is finished, the problem owner can direct his attention to another (perhaps a new unforeseen) problem which closes the cycle. In our case, the management of ECT has already done part of the problem solving cycle. They have perceived a problem in reality. Based on the problem situation as they see it, they have found one alternative solution.

The study presented in this paper deals with the assessment of this solution. It has to be checked if it indeed solves the problem in a satisfying way. For this, hard figures were needed of the terminal performance in the future compared to performance in the existing situation. As the models developed by management were not documented and not detailed enough to perform a rigid statistical analysis, we had to iterate the conceptualization-specification cycle again to develop models that would allow for such a statistical analysis. For these modelling efforts we used the LANE-approach, which is especially developed to deal with organizational problems that have strong dynamic interactions with other organizations.

## 3 Dynamic Modelling to support (inter-)organizational decision making.

As mentioned before, the problems in the Eemhaven case extend above the organizational level. The problem and its solutions are strongly affected by the way other organizations such as customs, trucking companies and other organizations will cooperate.

The following can serve as an illustration of this point. The trucking companies that bring the cargo to the Eemhaven Terminal are not the customers of ECT. In the transportation business, there are separate organizations called shipping-agents or forwarders that serve as an intermediary between the stevedore and the trucking company. Therefore, ECT cannot speak directly to the trucking companies about the improvements in the information system, but has to deal first with the shipping-agents.

So we are trying to solve problems that have solutions on the inter-organizational level. However, the value of these solutions can be found on the organizational level. Sol (1988) has made this distinction more explicit by identifying three perspectives from which we can view the system:

- The *macro-perspective* concerns the strategic planning of the organization in a societal sector. From this perspective an organizational network is perceived: a group of cooperating organizations that fundamentally retain their independence.

- The *meso-perspective* concerns the coordination of workplaces in an organization, with the aim of improving the performance of the organization as a whole.

- The *micro-perspective* concerns tasks of individuals or small groups at the so-called work places. The focus is on improving human performance.

The proposed solution aims at improving the performance of the stevedoring company. It is clear that inter-organizational efforts will be needed to reach this goal, which implies that there should be an advantage for the other organizations as well.

When it comes to modelling the system under consideration, we have to deal explicitly with these three different layers. We therefore propose a layered modelling approach called LANE, which stands for Layered Actors, Networks and Entities approach. It gives the modeler a rough guideline when he or she wants to construct a model of the current situation or a model of a possible future situation. LANE is based on two assessment techniques:

- In the first place the dynamic models created by the LANE approach are executable and can be used to perform a statistical analysis of the system under consideration.

- By means of visualization techniques, the modeler can present an animated view on the models constructed and thus on the system under consideration. This can lead to a better understanding and a better agreement of the possible future situations, especially when it comes to implications that are difficult to express in hard figures. Wierda (1991) has proven that this method leads to a better agreement on the problem and its possible solutions.

In the next section, we will describe how the LANE approach has been applied to the given problem.

## 4 The LANE-approach applied to the stevedore's problem

The LANE approach distinguishes Actors, Entities and Networks. Actors are active objects that handle passive objects, the Entities. Actors on the macro-level are the organizations and on the meso-level the departments within one organization. On the micro-level the actors are the employees of the organization. In this way, the LANE approach explicitly deals with the three perspectives as distinguished by Sol. The actors send entities such as containers and fax messages to each other and they send them over Networks, such as the road network or the telephone network.

Actors and entities can be described by using a notation that is borrowed from the object-oriented world. During the case study a tool called Fast-LANE has been developed to do the bookkeeping concerning the objects. The actions, carried out by the actors can be described by means of task structures, as developed by Bots (1989) as part of his task analysis technique. This technique is also used to depict the way of working of the LANE approach in figure 3. The little bombs in the task descriptions indicate that the task consists of sub-tasks and can therefore be "exploded". We can distinguish the three layers, as well as the sub-division between "conceptualization" and "specification". In the following we will describe the various activities that have been carried out in the ECT case. Note that the description seems to be linear, but that in fact we have carried out numerous iterations.

According to the LANE approach, the problem situation was analyzed from the three perspectives as defined above. In each perspective, a conceptualization as well as a specification activity is carried out. The result of the conceptualization activity is a data void, qualitative representation of reality. The specification activity combines this representation with the proper empirical figures.

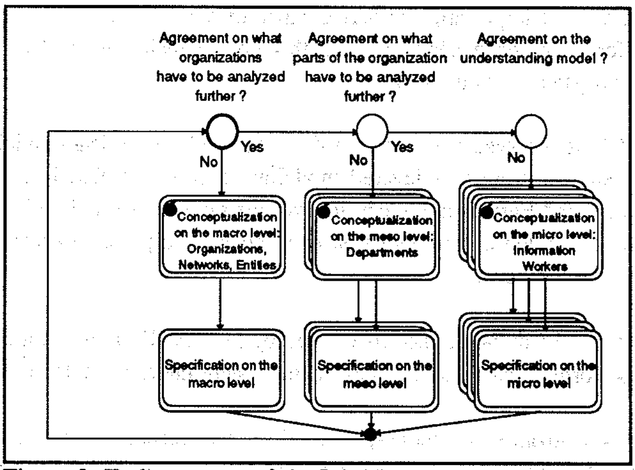


Figure 3: Task structure of the LANE approach

### 4.1 The macro level

From a macro perspective, it is important to demarcate the problem area. We have to determine what organizations are important for our problem, what networks connect them and what entities are being sent from one organization to another over what network. The potential participants can be determined when we look at the primary process of the interorganizational network: the transportation of cargo from shipper to consignee. In the typical case, the shipper sends a request to a forwarder who will then arrange the transport. The forwarder sends a shipping instruction to a shipping-agent and a transport request to a road transport organization. The shipping agent sends a loading instruction to the stevedore who takes care of the stowage in ocean vessels. The transport company sends a truck to the shipper to collect cargo and bring it to the stevedore for overseas shipment. The organizations involved are displayed in table 1.

| |
|---|
| Stevedoring company (ECT) |
| Transport Companies |
| Shippers |
| Forwarders |
| Consignees |
| Customs |

Table 1: Organizations on the macro level

The next step is then to achieve empirical figures about the operation of this complex system. Some figures are given in section one, but a lot more data could be incorporated in the model. We have determined which organizations play an important role in our problem domain. We have to zoom in to the meso-level to get more detailed information about these organizations. The entity flows all come together at ECT. Therefore there should be zoomed in to the meso level at least for the ECT organization. The meso perspective for ECT is presented in the next section.

## 4.2 The meso level

In this stage, we have to determine what actors and entities play major roles at ECT in handling cargo. This can be done by an analysis of the primary process of ECT. The LANE approach proposes to do this by following the entities through the system (material entities like trucks and containers as well as information entities like documents and fax messages). The result of this analysis is a detailed description of the processes that are carried out within the relevant parts of the system. This description can be extended with empirical data like interarrival time distributions of trucks, driving and handling time distributions etcetera. As an example, a terminal interarrival time distribution is given in figure 4. The next activity is to zoom in to the actual actions that are carried out by the actors in the relevant parts of the system in order to determine the factors that cause bottlenecks or delays. This is done by an analysis of the micro level, which is discussed in the next section.

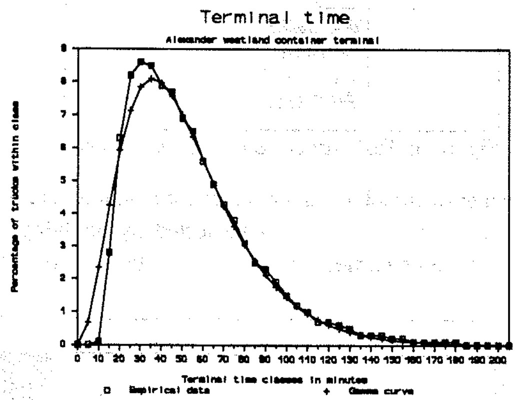


Figure 4: Example of a terminal interarrival time distribution

## 4.3 The micro level.

From a micro perspective, we look at the tasks to be carried out at the workplace. When these tasks are analyzed, empirical data about their duration can be combined with it in order to calculate delays and queue lengths. The tasks are described using the task analysis technique as proposed by Bots (1989). The task of an employee working at the administration desk for unloading services is given as an example in figure 5.

## 4.4 From description to improvement

After all the analysis activities, the qualitative and quantitative data can be incorporated in a discrete event simulation model, connected with an animation of the current situation. This simulation model can be validated by using standard statistical methods (replicative validation) and by showing the animation to field experts (structural validation). An example of an animation screen can be found in figure 6. After validation, experiments can be done with the descriptive model in order to obtain figures of the existing situation. These figures should be in accordance with empirical data. In order to obtain the desired 90 % confidence intervals, 20 replications of the model should be run.

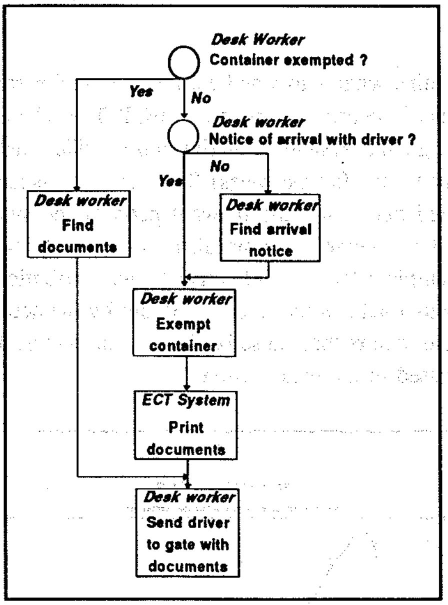


Figure 5: Task structure of a desk worker

Using the descriptive model as a base model, the alternatives for solution, like the implementation of EDI or more fax messages in a central gate setting, can be tested by applying these to the model. The conceptualization-specification has to be carried out one or more times. After this a number of 'what-if' questions can be answered.

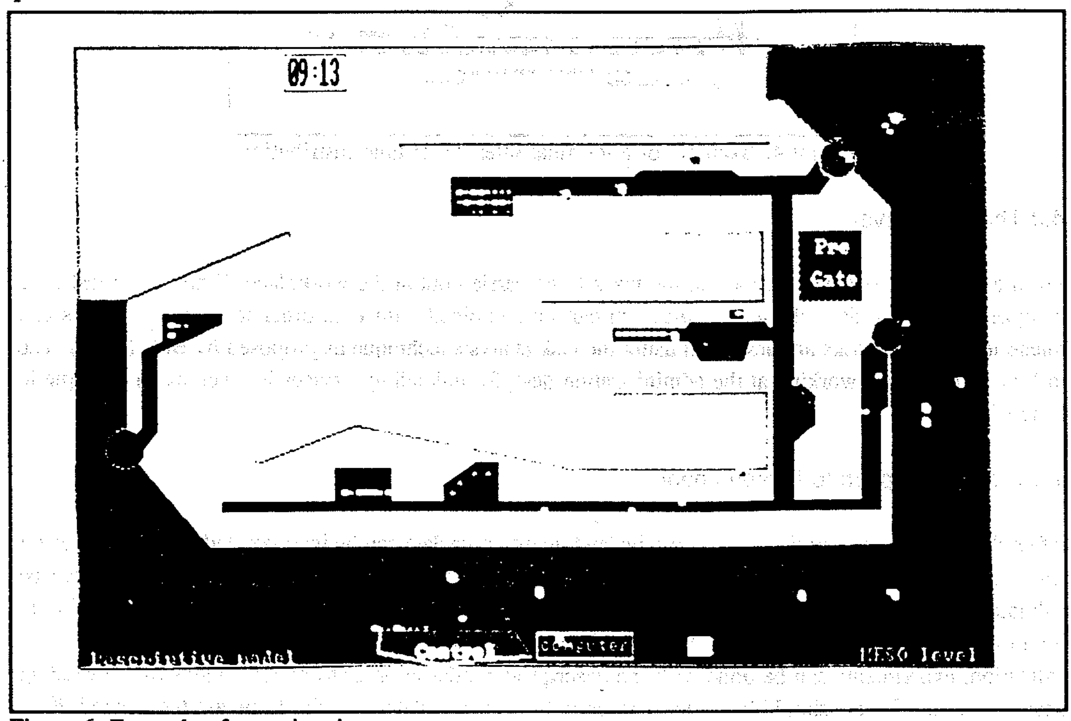


Figure 6: Example of an animation screen

## 5 Using the models in organizational decision making

Several changes and sub-solutions to the existing gate situation could be made. The changes were evaluated by implementing them in the simulation/animation model. We will discuss the results of each alternative briefly. An complete report of the results can be found in van Eijck (1992).

### 5.1 The centralized gate

The centralization of the gate was tested for performance improvement which includes handling times, queue lengths and traffic flow. Table 2 presents a comparison between existing and future situations for several key factors. A change of procedure at the administrative desks is incorporated in this solution. We recognize some substantial improvements. We also see that in a central gate situation, customized trucks have to wait longer because they are now in the same queue as container trucks.

| Variable | Existing situation | Central gate | Relative improvement |
|---|---|---|---|
| Avg. Handling time (Container trucks) (minutes) | 108.51 | 72.82 | 32.9 % |
| Avg. Handling time (Customized trucks) (minutes) | 96.82 | 128.73 | -32.9 % |
| Handling Time (Average total) (minutes) | 106.35 | 82.48 | 22.4 % |
| Max. Queue length (at parking place) | 81 | 61 | 24.7 % |

Table 2: Simulation results of central gate alternative

### 5.2 Desk capacity planning

The central gate model showed peak values for queue lengths and handling times in the morning hours. This was the reason for testing the central gate with more personnel capacity in these hours. This capacity shift caused another improvement of 4.2 % in average total handling time and another 22 % (!) in maximum parking space requirement. Our suggestion is to give extra attention to administrative desk capacity planning.

### 5.3 Fax and EDI usage

We also tested queue length and handling time as a function of the amount of fax usage by transport companies (the fax is sent ahead of the driver in order to obtain faster administrative handling at ECT desks). In the first experiment (the central gate) 5 % of the trucks were announced before arrival by fax message. Values of 10, 15 and 20 % were also tested. Figure 7 shows the total handling time as a function of the different fax usage percentages. We see a maximum extra improvement of 5.2 % at a usage rate of 20 %. Furthermore, the effects were tested of possible usage of EDI applications to notice truck drivers in advance. Rates of 5, 10, 15 and 20 % of EDI usage were tested, at a fax usage rate of 10 %. An extra improvement of 3.2 % could be reached, the results are presented in figure 8.

With fax usage, the maximum parking space requirements could be brought back to 49 trucks (which is an extra improvement of 19.6 %. With 10 % fax usage, the requirement for parking space could be brought back to 37 if 20 % of the trucks is noticed in advance with an EDI application (17.8 % extra improvement.

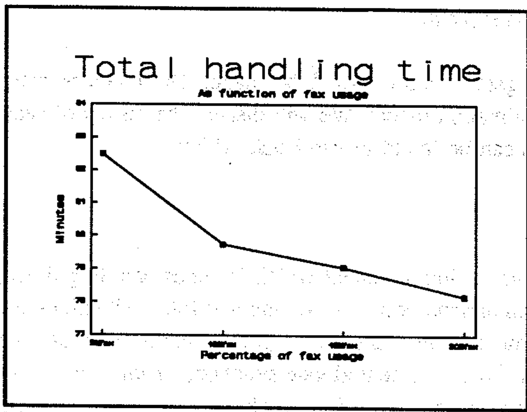


Figure 6: Handling time and fax usage

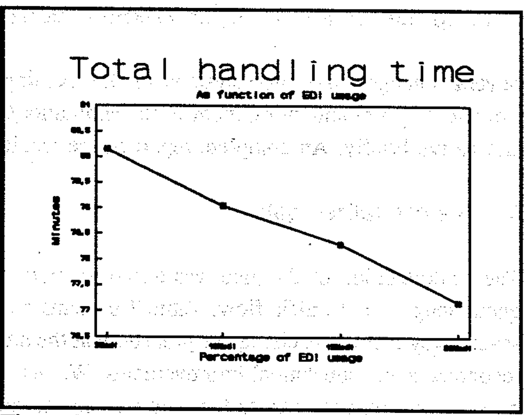


Figure 7: Handling time and EDI usage

## 6 Conclusions

Conclusions can be drawn with respect to the experimental results as well as to the methods that were used to achieve these results. With respect to the results, it was rather surprising that fax and EDI prearrival noticing has relatively little effect (less than 5 percent). The effects of replanning the gate and reengineering the business processes were much more spectacular (for some values more than 30 percent).

The methods that we label as dynamic modelling: simulation, animation and the LANE approach, helped a lot to get agreement about which part of the system should be examined more closely in order to get confident figures. Clearly it was impossible to investigate the whole situation as one complete system. The simulation and animation facilities clarified possible solutions and outcomes to management and workfloor.

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