

# Manpower planning in a general purpose shipterminal : an iterative aggregation-disaggregation-approach

**Citation for published version (APA):**

Demandt, H. M., & Wal, van der, J. (1983). *Manpower planning in a general purpose shipterminal : an iterative aggregation-disaggregation-approach*. (Memorandum COSOR; Vol. 8314). Technische Hogeschool Eindhoven.

**Document status and date:**

Published: 01/01/1983

**Document Version:**

Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

**Please check the document version of this publication:**

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

**General rights**

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

[www.tue.nl/taverne](http://www.tue.nl/taverne)

**Take down policy**

If you believe that this document breaches copyright please contact us at:

[openaccess@tue.nl](mailto:openaccess@tue.nl)

providing details and we will investigate your claim.

EINDHOVEN UNIVERSITY OF TECHNOLOGY  
Department of Mathematics and Computing Science

Memorandum COSOR 83-14

Manpower planning in a general purpose  
shipterminal; an iterative aggregation-  
disaggregation-approach

by

H.M. Demandt and J. van der Wal

Eindhoven, The Netherlands

September 1983

Manpower planning in a general purpose shipterminal;  
an iterative aggregation-disaggregation approach

by

H.M. Demandt and J. van der Wal

Abstract.

In a general purpose shipterminal ships arrive in order to be loaded, unloaded or both. The terminal has only a limited number of berth places, and ships arriving when all berths are occupied are lost to competing firms. By hiring extra manpower capacity ships can be served faster and leave earlier, so that fewer ships will be lost. The size of a detailed model will be tremendous. Therefore we have chosen for an iterative aggregation-disaggregation approach in which optimization alternates with simulation and adaptation of the model.

For this specific problem the method performs quite well, and we think it to be useful in other situations as well.

1. Introduction.

This paper deals with a manpowerplanning type of problem in a general purpose shipterminal. Ships arrive at the terminal in order to be loaded, unloaded or both. Ships arriving when all berth places are occupied are lost; they turn away to competing firms. The loading and unloading requires manpower and hardware, like cranes and forktrucks. In the decision problem treated here one has to decide weekly upon the amount of manpower within certain limitations due to restrictions in the hardware. There is a second very important aspect of the problem which has to be taken into account : the day-to-day assignment of the manpower to the ships. Further there is some information about ships arriving in the near future.

Together this makes the size of the problem tremendous and it is impossible to obtain an optimal solution.

However, the difference in time scale between the weekly planning and daily assignment decision suggests that aggregation might be a very sensible approach.

After a more precise statement of the problem in section 2 we will formulate in section 3 an iterative aggregation-disaggregation approach, in which optimization in the aggregated model for the weekly decisions alternates with a simulation run of the daily assignments.

The outcomes of the simulation are used to correct the model assumptions in the aggregated model. In sections 4 and 5 the aggregation and simulation models are described. Finally the numerical results are shown in section 6. This paper is in a sense a sequel of [1]. For remarks on relevant related work see the introduction there.

## 2. Detailed description of the problem.

At a ship terminal ships arrive in order to load, to unload or to do both. The stevedore who has to control the process faces the following problem.

On the one hand the ships have to be served as fast as possible because :

- a) there is only a limited number of berths and an arriving ship which finds all berths occupied is lost to a competing firm;
- b) ships do not want to be delayed.

On the other hand the amount of manpower employed has to be kept as constant as possible to reduce the costs.

Next the following aspects of the problem are described in greater detail :

- the arrival process;
- the work in a ship;
- the way ships are served;
- the workpattern;
- the manpower.

### The arrival process.

Ships arrive according to a Poisson process with an average of 16 ships per week. There is some information about the number of arrivals in the next week but little or no information about the amount of work in the ships.

### The work in a ship.

Typically a ship has several, usually 5, holds. Each hold corresponds to an amount of work. With respect to this amount one has to distinguish between the number of men required and the time needed to do the job.

Increasing the number of men not necessarily reduces the time. For simplicity we assume that all workcrews are of the same fixed size of 10 men. On each hold only one crew can work at a time. The hold of a ship requiring the longest service time is called the *heavy* hold.

The way ships are served.

Each ship has to be served in the time needed to handle the heavy hold. A small delay may be acceptable.

The workpattern.

The week consists of 21 periods of 8 hours, 11 of which are working periods. Namely, Monday till Saturday from 08.00 to 16.00 and Monday till Friday from 16.00 to 24.00. During the 08.00 - 16.00 shift (except Saturday) twice as many men are available as during the other shifts.

The manpower.

The total workforce is divided into three categories :

- a) 150 men, so 15 crews, who are always available;
  - b) a 'guarantee' of 150 men in a pool of laborers shared with the other stevedores in the harbour. When these men are hired they cost a little more (10%) than the regulars. If not hired they still cost 60%;
  - c) above the guarantee you can get more men from the pool at a cost of 150%.
- In all three categories the men are employed according to the 2 : 1 ratio mentioned before.

When we are going to formulate the process as a Markov decision problem we will have to specify the states and the decisions.

The states.

A full description of the states of the process has to contain : the number of ships present, the amount of work in each hold, the already available information about the arriving ships, the timeperiod within the week, the number of crews available according to the decision of last Saturday.

The decisions.

There are two types of decisions :

- a) the weekly decision on the amount of men to be hired from the pool. This decision has to be taken at Saturday 16.00 h.;
- b) the day-to-day assignments of crews to holds.

3. The iterative aggregation-disaggregation approach.

Clearly the number of states will be too large. Also the decision structure is quite complicated.

So it will be impossible to determine an optimal solution for the problem. The two types of decisions and the difference in timescale between them suggest that it should be possible to obtain a good solution by first taking the weekly decision about the number of men to hire on the basis of some aggregated information. And to take the assignment decisions for a given weekly decision. Observe that the assignment problem is not very complicated here. Because of the restriction that ships should not be delayed too much it is natural to assign the crews to the heaviest holds. And since it is attractive to have empty berth places, one should start to assign to the smaller ships. This leads us to the following assignment rule :

- first assign a crew to all the heavy holds, starting with the smallest ones;
- next, if not all crews have been assigned already, assign a crew to the next-heavy holds (the one which will become heavy the next period) starting again with the smallest ones, etc.

The difficulty lies in the formulation of the aggregated model. We want that the optimal strategy obtained for it is good. This, however, requires that we can correctly 'guess' the various parameters of the aggregated model, like e.g. the transition probabilities. Since in general this is not possible, we propose the following approach :

Iterative aggregation-disaggregation method.

Alternate between steps (i) and (ii) until convergence :

- (i ) Formulate an aggregated model for the weekly decision and determine an optimal strategy for it.
- (ii) Use this optimal strategy in a simulation to see whether the assumptions on the parameters of the aggregated model were correct. If necessary update the model.

In the next two sections the steps (i) and (ii) are worked out in more detail.

#### 4. The aggregated model.

The problem of the weekly decision is formulated as a Markov decision process. In the formulation we will take as a unit of work a 'standard ship equivalent', i.e. the amount of work corresponding to an average ship. The average number of shifts one crew would need to serve a ship is 8. So, with crews of 10 men a standard ship is equivalent corresponds to 80 mandays of work.

To get the Markov decision process formulation we will subsequently consider the states, the decisions, the transition probabilities and the costs.

#### The states.

The states will be two-dimensional. First we have to know how many ships are present and how much work they contain. We ought to distinguish between the number of occupied berths and the amount of work. In the state description we only use the number of occupied berths. The number of standard ship equivalents is obtained from it by multiplication with a 'loadfactor' e.g. 2/3.

The second dimension is the number of ships expected to arrive the next week (the next 168 hours). This number varies between 8 and 29 and its distribution is determined from the Poisson distribution with average 16. As a result the total number of states will be  $13 \times 22 = 286$  (13 berth situations :

0,1,...,12, and 22 arrival informations : 8,9,...,29).

#### The decisions.

The decisions are just the number of ship equivalents to serve. There are a few restrictions on these numbers. E.g. at least all the regulars should work, and no more crews than cranes (the number of cranes is 27).

#### The transition probabilities.

It is very hard to make a good guess about the transition probabilities. There are at least 4 aspects playing a role.

- The number of ships that actually arrives may differ from the expected number.
- The arrival times are random, roughly homogeneously distributed over the week (a property of the Poisson process). The randomness of the arrivals may cause idleness of the manpower and may also make that ships are lost unexpectedly because all berths are occupied at the arrival instant.
- Disturbances like bad weather and illnesses. (These however we ignored).
- The number of ships to arrive the week after the next week is a random variable.

The initial guesses we made were not very good.

#### The costs.

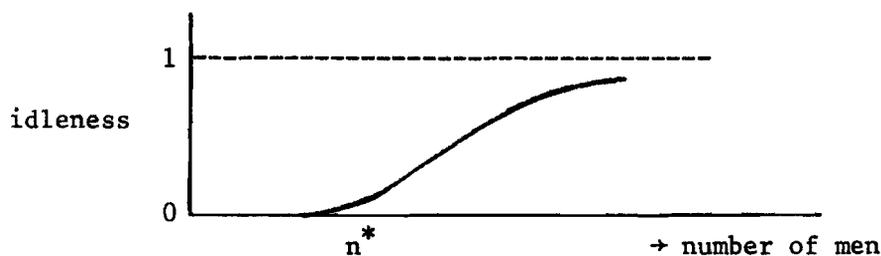
There are costs for the manpower and costs for loosing a ship. Also one may add costs for delaying a ship, but then we also need the probabilities of delay. As this would be very complicated we did not take delay costs into account. However we carefully looked at outcomes of the simulation to see whether the delays were still acceptable.

To obtain an optimal (or nearly-optimal) strategy we used a standard successive approximation method, which for a problem with so much randomness as this one converges very rapidly. The result is a strategy which says how many men to hire depending on the number of ships present and the expected number of arriving ships.

5. The simulation.

The simulation has to be organized in such a way that the outcomes enable us to improve especially the transition probabilities and the costs of the aggregated model. The simulation however is too time consuming to actually obtain the transition probabilities. Therefore we concentrated on two parameters which seemed to be the most important ones, the idleness of the manpower and the multiplication factor which translates occupied berths to standard ship equivalents.

Clearly the idleness, and maybe the multiplication factor as well, depends on the states as well as the decision. The idleness fraction for a given initial situation (at Saturday 16.00 h.) will vary with the number of men hired as indicated below :



Close to the computed optimal decision  $n^*$  the idleness will vary roughly in a linear way. So what has to be determined is the slope. For this a few decisions around the optimal one have to be investigated. (To avoid difficulties only these decisions will be allowed in the next aggregated model).

Two more simplifications were made to reduce the simulation effort.

- (i) We did not consider all states. For each number of arrivals we simulated only one initial berth occupation. Clearly this gives a serious reduction but it also makes the outcomes less accurate. The idleness behaviour obtained for the optimal decision  $n(a,b)$  for number of arrivals  $a$  and berth occupation  $b$  is translated to berth occupation  $b'$  as follows.

Let  $n(a,b')$  be the optimal decision in state  $(a,b')$  then the idleness in  $(a,b')$  for decision  $n(a,b')$  is set equal to the idleness for  $n(a,b)$  in  $(a,b)$ . Since most of the idleness lies at the end of the week this must be quite reasonable.

The initial berth occupation, specified by the number of ships and the amount of work for each hold, was also derived from a small simulation.

(ii) Since the arrival process is Poisson the arrival times are uniformly distributed once the total number of arrivals is given. To reduce the randomness in the outcomes due to this random arrival process would require long simulations. To avoid this we have chosen four arrival patterns which together represent the Poisson arrivals quite good.

For each arriving ship the work for each hold was drawn randomly.

## 6. Numerical results.

The method produces a lot of data, especially in the simulation runs. We give only a few of them. The main result concerns the convergence of the method. Table 1 below gives some results obtained in the aggregation phase.

	Run 1	Run 2	Run 3	Run 4	Run 5
Cost/week	350.000	408.000	363.000	361.000	361.000
Idleness	0.0 %	18.0 %	3.5 %	2.3 %	2.1 %
Lost ships	0.1 %	11.5 %	3.2 %	2.9 %	2.8 %

Table 1. Average cost per week, idleness and number of lost ships. Cost per man per week 1125, cost per lost ship 25000.

The multiplication factor translating occupied berth places to standard ship equivalents was about 2/3 and hardly varied through the iteration process. The average delay in the last simulation run was 1 day, which compared to the average time to serve a ship of 4 days is somewhat large. Practically all delays occur in the 16.00 - 24.00 h shift and on Saturday. This clearly is the result of the 2 : 1 restriction and it is unavoidable unless this restriction is relaxed.

Concluding we can say that the method converges fast and that the results are quite good.

The accuracy of the method is sufficient to investigate changes in the decision structure like :

- Take the weekly decision at Sunday evening instead of Saturday.
- Change the 2 : 1 ratio into 3 : 2.
- Work 24 hours a day and 5 days a week.
- Work 168 hours a week.

Finally, we think that iterative aggregation-disaggregation methods of this form may be very useful in other situations as well. In practice stochastic decision problems may have huge state spaces and aggregation is often very difficult because of the necessity to specify values for parameters describing some kind of aggregated behaviour. Especially then an approach like the one presented here may be of help.

o-o-o

#### References.

- [1] Lenssen, M.J.G., J. van der Wal and J. Wessels, Markov decision processes and ship handling : an exercise in aggregation, in Operations Research Proceedings (1982), Springer Verlag, 476-482.

o-o-o