Module name: Service Systems in Ports and Inland Waterways

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QUEUING NOTATIONS

P(j)	Steady state probability of having j clients in the system
λ	Arrival rate
μ	Service rate
ρ	λ/μ
n	Number of berths
u	Utilisation $(=\frac{\lambda}{\mu * n})$
W	Average waiting time of customers spent in queue
W (t)	p.d.f. waiting times
N_w	Average number of customers in the queue
N_a	Average number of customers in the system
ν_a	Degree of variability of arrival intervals - $(c.v.)^2$
ν_s	Degree of variability of service intervals - $(c.v.)^2$
c.v.	Coefficient of variation of a distribution - standard deviation/mean
s.d.	Standard deviation
T	Average turnaround time (waiting time + service time)

1. Introduction

With the planning of a port development or the design of a new port, one is confronted with unique physical properties, boundary conditions and problems to be solved. What ports have in common is that they all constitute a link in the transport chain and an interface between transport modes. As a result every port comprises a number of systems:

a. The wet infrastructure
   - approach channel(s)
   - manoeuvring areas
   - mooring basins

b. A system of aids to navigate, to enable the ship to make a safe landfall
   - system of towage
   - pilot system

c. The dry infrastructure
   - terminals with cargo handling and storage facilities
   - through transport systems

In port studies, generally two main subjects can be identified, viz. improvement of the existing situation, and design of a required future situation.
For the purpose of optimising port facilities in relation to capacities demands, port operations have to be analysed, a process which is often facilitated by applying complex port simulation-models. However sometimes a relatively simple empirical approach or queuing theory can be used. Concerning the choice of the method, always due attention should be paid to the local situation.

In Chapter 2 a brief description is given of the procedure followed in port studies. The general aspects concerning the port design are the subject of Chapter 3. In Chapter 4 a closer look is taken at the possible solutions of the design problem, i.e. 'rules of thumb', queuing theory and simulation models, with increasing complexity. Much attention is paid to the Queuing Theory, which is the subject of Chapter 5. The most complex problems are solved with the aid of simulation models, which are treated in Chapter 6. The analysis of the input and output data concerning these models is the subject op Chapter 7.

The Chapters 1 to 5 are part of the lecture notes of Ct4330 while Chapter 6 and 7 belong to the lectures of Ct5306.

2. Port studies

In order to analyse and evaluate the complex system of transport modes which come together at a port, a clear specification of the objectives and criteria is a required starting point for any port study which involves planning and design of future developments.

A port study is normally carried out according the following procedure:

i. Generation of alternatives
- analysis of the present and or anticipated cargo flows
- determinations of the transport modes leading to traffic forecasts (as shipping).
- principle dimensions resulting in a number of alternatives

ii. Refinement
- screening of alternatives
- preliminary engineering and conceptual plans of the selected alternatives
- selection of the most promising alternative.

iii. Finalisation
- detailed design and recommendations including the time dependent upgrading steps.

An important criterion for evaluation of alternatives is "minimum total costs". The minimum of total costs is mainly determined by two main components:

i. Capital and maintenance costs of port infrastructure and facilities and
ii. Vessel time in the port and associated with costs,

As these components are interdependent, they have to be duly and jointly investigated for varying cargo and traffic volumes.

The study hinges on the comparison of the various alternatives and the optimisation of the most promising alternatives.

3. Aspects in port design

3.1. Introduction

The ultimate symptom of port operational problems is congestion. The cause of congestion is not always easy to discern, but the symptoms can hardly be missed. The symptom referred to, is one of the following signs of congestion, or a combination thereof:

1. Every regular storage space is full and a considerable amount of goods is on the quays
2. A long queue of ships is waiting at the anchorage for a berth
3. There are queues of trucks or other means of inland transport.
4. Surcharges are levied on cargo carried to or from the port.

These symptoms may aggravate each other. If for example, the quay is for the most part occupied with cargo, the remaining working spaces are inadequate and cargo throughput capacity will be more limited. This may result in fewer ships being served, causing longer queues. The causes may be either physical limitations in ship handling and cargo handling or organisational limitations.

The most important causes are summarised in the next paragraphs.

3.2. Organisation

3.2.1. Port management

A thorough study of the local organisation and related procedures is essential when attempting to optimise the throughput of an existing port or when a master plan is being made for future extensions or a new port. By simply improving the procedures a considerable gain in the operation of the port as a whole, can often be obtained. This improved situation may defer the implementation of future physical extensions.
A very common problem is divided management. In some ports the port management isn't under a single authority and divided between central and local governmental institutions.

A special problem for very small ports is that many tasks (port administration, port operations, harbour master and port engineering) may be in the hands of one man, resulting in an overloaded day - to - day program. Consequently little time is available for planning of future developments or even for short-term improvements of operation efficiency.

3.2.2. Cargo handling, stevedoring

Delays in cargo delivery, cumbersome customs procedures and payment methods for duties and port charges greatly contribute to the inefficiency in cargo handling. One reason, which is often overlooked, is the overflow of storage facilities because the storage tariff is too low and the consignee is tempted to use the port facilities as long-term rather than short-term storage. In addition, care should be taken to ensure that stevedoring and the related administration is efficient. Sometimes, the location of cargo is not recorded and a search for goods is necessary when they are due for collection.

3.2.3. Planning, information, communications

With the limited infrastructure and equipment, typical of many ports in developing countries, smooth

operation is only possible with a careful planning and execution. This requires quick acquisition of information and efficient communications with foremen, charge hands, etc.

Berth allocation by the harbour master should obviously be co-ordinated with cargo handling plans. When releasing entrance permit, the harbour master should consult the cargo handling officer to ensure that equipment and manpower are available for the cargo handling and, in case of imports, that enough space is available in transit sheds or other temporary storage.

The full capacity of the infrastructure can only be achieved if entrance criteria are established with due regard to environmental conditions related to safe navigation in the port and its approaches. Consequently, the harbour master should be kept informed about these conditions. The poorer the quality of this information, the greater the safety margins which have to be applied, the longer times are necessary because of the safety margin needed.

3.2.4. Training

The skill of personnel involved in port operations strongly affects the functioning of a port. The extent of training to the level of skill required, and the throughput and/or efficiency of a port (or dimensions of a new port) are very much interrelated. It is stressed that appropriate permanent training facilities should be available locally: a single training course in a developed country may be fruitful for a short period but the experience obtained will fade away quickly. Training courses, adapted to local customs and procedures have to be given to all relevant personnel and at regular intervals. For instance courses for pilots, tugboat crews, harbour masters and terminal operators should preferably and predominantly be given in the home port.

3.3. Ship handling

3.3.1. Berths

A very important item in port operations is the ready availability of adequate berth capacity, when it is required. Too few berths will give rise to queues for ships and delay in cargo delivery. Berths that are too small, limit the maximum ship size, which in turn limits the throughput capacity.

Berths in unprotected or relatively exposed locations give special problems. Under unfavourable wind or swell conditions ships have to leave their berths to prevent damage from impacts with harbour structures and other ships or breaking of mooring lines. In countries which have a storm season, these, what are referred to as 'survival conditions', may be a factor hampering port operations in that season (i.e. conditions for which the port infra structure has to be designed to survive, but during which no cargo handling operations are possible). Breakwaters can help considerably against swell and currents. Berth orientation also plays an important role. For instance, a berth perpendicular to the prevailing storm directions will have a larger downtime because of an earlier attainment of the survival conditions, than a parallel berth.

3.3.2. Entrance

The requirement that a ship can enter and leave the port safely is as equally important to port efficiency as the availability of berths. Although this is rather obvious, the consequences are not always fully recognised. The nautical operational limits can effect the port efficiency drastically. These limits are dependent on ship type and class, environmental conditions and the port layout and dimensions.
The conditions for which entry is considered safe or unsafe are referred to as the port entrance regime. If