MEASURING PORT PERFORMANCE

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1 - PREAMBLE

This note proposes a more customized approach of indicators used to monitor port performance, forecast development and set targets in port sector projects. The main points are that, in most cases, it is not possible to determine benchmarks which would be applicable for any port, and that all expressions of port performance do not address the same requirements. Therefore, carefully identifying problems to be monitored and taking into account the main characteristics of the commercial activity should lead to more accurate indicators and targets.

Available data: In public ports, expressions of port performance are based on data recorded by port authorities which traditionally tend to focus on traffic recordings and parameters used in tariffing of port services. Most available and reliable data are related to the maritime interface where information is more easily collected than on the land interface. Port Authorities usually monitor berth occupancy and dwelling time of ships, characteristics of calls, performance of ship-to-shore cargo handling and availability of the main pieces of handling equipment. Additional but often less reliable data may be available as regards landward operations: dwelling time of cargo in ports' warehouses and storage areas, characteristics of Customs and other administrative procedures and, rarely, performance of handling for pick-up and delivery of goods...

Most of the time, developing a relevant set of indicators would require more information; a survey is the only way to identify whether existing data are reliable, the cause and extent of existing problems and the way they could be monitored.

Whatever criteria are chosen, they must be associated with a precise definition of what is recorded, as all port authorities do not take into account all parameters the same way; for example, they may include empty containers, shifted and transshipped boxes or the tare weight of unitized goods.

Forecast: These indicators are often used to forecast port productivity and assess future capacity. Computerized simulation systems can give accurate estimates of berth capacity and ships' waiting time. Various statistical programs designed for all purpose process modeling or specialized in transportation and port logistics may be used. This note will remind of some simplifications of the queuing theory, which can give rough estimates in some simple cases.

Performance and competitiveness: These expressions of performance display mainly a technical capacity. But shippers and ship-owners have additional requirements; they are also looking for:

- reliability: a steady and predictable performance adapted to shipping lines schedules;
- cost: a high performance at a competitive and predictable cost;
- quality: no overage, no wastage or pilferage or any damage registered during handling and storage operations. Progressively, producers and transporters have to comply with international standards (ISO 9000 or equivalent) and get their process certified; ports, at least those operating in a competitive environment, have to catch up with this trend;
- adaptability: a capacity to listen to their problems and needs, negotiate and propose solutions.

A port is also a link in the transport chain and, of course, similar requirements apply as regards capacity, performance and quality of connections with short-sea and feeder shipping lines, and with inland transportation networks : road, rail, barges.

Complying with these requirements results is competitiveness and, ultimately, growing market share; ports process more traffic and shippers benefit from lower freight rates and insurance premiums. This can be assessed mainly indirectly. Fortunately, performance and competitiveness are more or less linked: high productivity is often synonymous with reliability and quality and, not systematically, with low costs. Therefore, performance and cost targets are an acceptable approximation of competitiveness.

1.2- technical valuation of port performance

Port operations are increasingly specialized and processed in dedicated terminals but many flows of goods are still handled at general purpose berths. Depending on the case, port performance should be assessed for an homogenous set of berths or a terminal. It is usually expressed as the average number of calls and the average flow–volume or weight–of goods over a standard period of time; number of calls per berth and per year, volume or weight of cargo handled per hour, per call or per day, per gang or per crane.

In addition, other criteria can be used to see how existing capacity and performance meet the requirements of: i) the shipper or the ship-owner: mainly average waiting time of ship, dwelling time of cargo and data related to quality if possible, and: ii) of the Port Authority: basically berth occupancy rate and global traffic.

All these parameters are not equivalent:

- “snap-shot”performance (recorded during an hour, a shift, a call) describes the technical capacity of a terminal; a flow of goods recorded within a larger period depends also on parameters related to competitiveness, market share, seasonal effects, berthing capacity etc.

- Some of them are used to monitor specific points of concern for port authorities, operators or clients and cannot improve simultaneously. For example, Port Authorities are looking for relatively high berth occupancy rates whereas shippers do not accept significant waiting time.

1.3- explanatory factors

High performance is observed in private terminals and poorest performance is often associated with ports run by public Port Authorities, still in charge of cargo handling and maintenance of equipment. Beyond such a statement, explaining a poor or a good performance may require a more thorough analysis.

Exceptionally high performances occur when all parameters concur positively: as far as containers are concerned, the typical high-performing terminal is dedicated to one or a few shipping lines and privately run, processes regular and well timed calls of large ships, with economies of scale allowing it to be geared with the most high-performing gantry cranes, and handles shipments representing the major part of the ship capacity. Similar parameters can be mentioned in the case of bulk (freighted) traffic.

Conversely, in poor performing ports, many causes, often interrelated, may be mentioned,:

- Physical characteristics, mainly: nautical access: dredging backlog and other factors narrowing the access time-slot; land access: ill-maintained pavements, restricted access to land-transportation networks; and port capacity: lack of berths and storage areas, insufficient room for modern ship to shore operations;

- Organizational parameters, related to ships: old ships with narrow hatches, large tween decks, slow moving derricks, spending too long idle time at berth; cargo: ill packaged, non unitized, damaged goods, organization of lashing-unlashing of containers; handling capacity: unsuitable and ill-maintained handling equipment, poorly trained work force, not enough crane drivers, unsuitable, congested and poorly managed storage areas; organization: non-productive methods, ill prepared calls, too restricted working-time, unwillingness of port operators to work at night, commercial operations interfering with ship-to-shore operations, excessive dwelling time of cargo for commercial motives, documentation delays; procedures: lengthy customs and other administrative procedures and controls, corruption.

Public port authorities but also other administrations, port operators, ship-owners, and shippers, involved in this process with their own objectives, may be partly responsible for these shortcomings. A rapid survey of the situation should help identify the main causes of the problems and choose adapted criteria to monitor further progress.

1.4- measuring port performances - basics

Poor performances are generally due to the organization of handling and storage operations and of maintenance. Therefore, the most common and practical way to measure port performance is to check whether organization and yard equipment can match the actual capacity of the main hoisting machines: generally quay cranes or gantries, which are the most expensive and high-performing pieces of equipment.

The first step consists in determining the nominal and the optimum–or commercial–output:

- The nominal output of a crane or a gantry is the theoretical result when all parameters are optimized and reliability is absolute; it can be precisely assessed by taking into account :

  . the average load to be handled:

    .. break-bulk and unitized traffic: unit load plus accessories: spreaders... ;

    .. dry bulk traffic : weight of buckets plus capacity x density of product,

- the average duration of a whole handling cycle (loading or unloading), taking into account the length and speed of each elementary move: hoist, translation, rotation, lowering and back to hold, with and without the load, according to the manufacturer's technical specifications;

- The commercial output is lower; due to various factors:

  . physical factors such as nautical and weather conditions impairing average performance: tide, swell, wind or rain;

  . factors related to port operations: average ships' characteristics, time spent in stowage, trimming, for opening or closing of hatch-covers, lashing-unlashing of containers, etc.

  . equipment related factors: standard reliability of cranes, the time it takes to shift them, to change buckets or spreaders, and organization of work, i.e.: proportion of effective work-time during a shift;

The second step is to identify the main causes of poor performance and choosing adapted and measurable criteria.

Over a long period of time, additional delays must be deduced from the commercial output to take into account the extra time spent by ships when they are berthed, before and after commercial operations, waiting for various motives: due to nautical and weather constraints, because of locks or swaying bridges, waiting for port services (bunkerage, repairs), because of non flexible working time.

Benchmark: Most container gantry cranes have a theoretical output of 35 to 40 moves per hour or more. The commercial output, depending on local conditions, varies usually from 15 to 35 in average, with peak performance nearing theoretical performance.

The Delta Sea-Land Terminal at Rotterdam has recently invested in double-trolley gantry cranes and a fully integrated and automatized system between ships and stacking areas which is intended to reach 50 TEUs per hour and per hold, i.e., almost doubling the usual output.

In the case of continuous handling of bulk products, the commercial performance may be closer to the theoretical output (80 to 90 %) with peak performance exceeding theoretical performance, depending on the reliability of equipment and the characteristics and number of products to be handled during a call.

As far as the performance of the land interface is concerned, the problem is generally the lack of data;

- Average cargo dwelling time. A distinction should be drawn between the impact of customs and other administrative procedures, of shortcomings in storage management and cargo handling, and of commercial practices (e.g., when port storage is less expensive than private warehousing). The average dwelling time should not exceed 5 days for containers, 7 to 10 days for general cargo, two weeks for bulk products. Commercial constraints may lead to longer delays.

- the average time spent by a trailer waiting for its load to be located, handled, and to get its clearance, is usually known only through occasional surveys, even though pick-up and delivery of goods often accounts for a large part of the port congestion and inefficiency. It should not exceed 4 to 6 hours. 2 hours are the norm in modern container terminals.

Regarding equipment reliability, two parameters must be identified: i) the reliability in operation, i.e., the number and length of breakdowns occurring during commercial operations and: ii) the average availa-bility, after deduction of planned maintenance and all breakdowns.

For small pieces of equipment like tractors, trailers, forklifts, availability should be very high (95 % or higher), provided that their number matches the demand and standard preventive maintenance is performed.

Regarding gantries, cranes, RTGs, breakdowns may occur and stop port operations; with normal preventive maintenance, most of them should be limited to electricity and automation problems and repaired within a few hours. Availability should be more than 90 %. The norm in modern terminals is close to 98 %, or 2% unscheduled downtime.

An occasional lack of gantry-cranes drivers may reduce the above availability ; this parameter is not always identified.

2 - APPLICATION

2.1 - containers

Container terminals performance depends on:

- ratio loaded vs. unloaded containers: empty boxes are not always included in the port statistics (they may be considered as other tare weights) but have to be handled;

- unproductive moves, i.e., the handling of all the containers that do not have to be unloaded but have to be moved: mostly empty and light containers and those containing hazardous materials, loaded on top or on the deck;

- the level of automation of the gantry-cranes; one of the limiting phases of the handling cycle is the time spent positioning accurately the spreader on a container (loading), or the container on a trailer, a MAFI trailer (specialized equipment used to shift containers within port limits) or a chassis maneuvering on the apron (unloading).

  Most modern gantries are automated and equipped with anti-sway devices, and now, the problem is more the capacity to deliver or remove containers without delaying ship-to-shore operations.

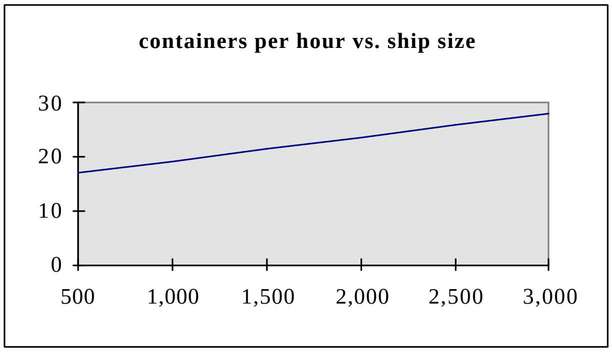
- the average weight of containers and the proportion of containers requiring special attention: flats, liquid bulks, reefers etc.; and the mix of containers of various sizes: 20’/40’/45’ which will require to maneuver or change spreaders;

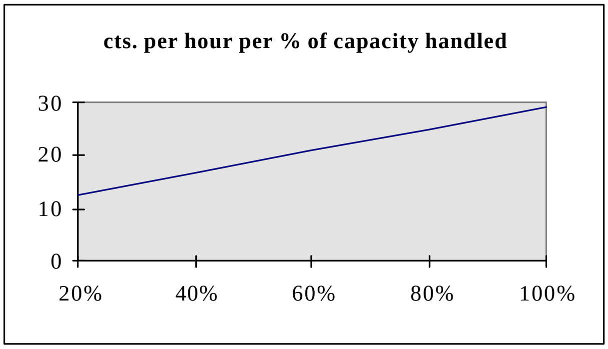
- commercial constraints; most of the lines calling at a port may have similar commercial constraints, leading to unevenly distributed calls.

Highest performance is observed during calls of large container-carriers loading and unloading a large number of containers, with balanced flows of full containers in and out; terminals dedicated to a single company can be highly productive (mainly East-West traffic);

Various analytical approaches have been proposed; in 1998, Drewry proposed linear functions of the vessel size and of the proportion of the ship's capacity to be handled during one call.

(source: Drewry Shipping consultants: World Container Terminals 1997).





As far as costs are concerned, and since containerization is a completely standardized process, it is widely accepted that there is a single benchmark for all terminals operating a main flow of containers in optimum conditions: about US$100 for all handling and storage costs from ship to gate. Practically, real costs may vary from US$ 80-90 in some terminals to more than US$ 400.

the case study below compares two different situations in order to demonstrate how different parameters may affect performances.

Case no. 1: ship size: 3rd generation and larger, length: about 300 m, calling for 1,000 containers or 1,500 TEUs, average load per TEU:10 ton, proportion of 40-foot containers: 50 %, proportion of empty containers: 10 %, 2 to 3 gantries per ship (3 gangs),

In that case, the capacity of the gantry cranes can be fully exploited: the commercial output can be 25 to 30 move / hour / crane in average.

According to the above assumptions, performances can be expressed as follows:

TEU $_f$ = TEU full TEU $_e$ = TEU empty

ratios : 37.5 to 45 TEU $_{f+e}$ /hour/gantry, 34 to 40 TEU $_f$ /hour/gantry

94 to 135 TEU $_{f+e}$ /hour, 85 to 120 TEU $_f$ /hour, 850 to 1,200 ton/hour,

2 to 3 shifts are required

1 call / 2 days, 180 calls, 180,000 cts *2 calls / 3 days, 240 calls,240,000 cts*

240,000 TEU $_f$ /year [1], 320,000 TEU $_f$ /year

2,400,000 ton/year, 3,200,000 ton/year

8,000 ton/year per meter of berth 10,600 ton/year/meter of berth

This computation presupposes that several berths are available; a one berth configuration would not be flexible enough and could not perform efficiently; as soon as ships are moored, stevedoring operations are supposed to start; they sail off at the end of commercial operations without delay.

Ratios higher than 10,000 ton/year per meter of quay length may be obtained: i) when large container carriers are fully loaded or unloaded; ii) if traffic and port organization allow to raise the berth occupancy rate without congestion; for example, with 6 calls per week, i.e., 300 calls per year, the ratio becomes: 13,250 ton/year/meter of berth.

Conversely, lower performances are recorded when smaller container-carriers call for a limited number of containers and have to handle many empty boxes (mainly North-South traffic);

case no. 2 ship size: 1st and 2nd generation, length: less than 250 m, calling for 700 TEUs or 500 containers, average load per TEU: 13 ton, proportion of 40-foot containers: 40 %, proportion of empty containers: 30 %, 1 to 2 cranes and 1 or 2 ship derricks (3 gangs) per call, 2 calls every 3 days;

Performance: 20 to 25 move/hour with gantry-crane, 12 to 15 move/hour with cranes or derricks,

With this new set of assumptions, the former expressions of performance are modified as follows:

ratios : 28 to 35 TEU $_{f+e}$ /hour/gantry, 17 to 21 TEU $_{f+e}$ /hour/ crane or derrick,

62 to 91 TEU $_{f+e}$ /hour,

20 to 25 TEU $_f$ /hour/gantry, 12 to 15 TEU $_f$ /hour/ crane or derrick,

44 to 65 TEU $_f$ /hour/,

572 to 845 ton/hour,

2 shifts are required

120,000 TEU/year per berth, ([1] cf previous case)

1,550,000 ton/year, 6,200 ton/year per meter of berth length.

This last result must be compared with 10,000 ton/m in case no.1; both examples correspond to different but well operated terminals.

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[1] loaded containers; this ratio does not depend on the hourly performance, except from a commercial standpoint.

2.2- break-bulk :

Due to the wide range of products, ships, equipment, methods..., assuming an average performance for all kinds of commodities and packaging makes little sense:

- Specialized traffic like paper, frozen meat, fish or fruits should be studied separately, according to their packaging and to the type of ship and handling equipment (specialized or not); see appendix one, the case of fruit handling.
- Most commodities in big bags, pre-slung or pre-palletized loads, pallets, nets etc., can be handled with a crane; a good organization should adapt to a rhythm of one cycle every 1.5 to 3 minutes (20 to 40 moves per hour), depending on the nature of the cargo, the unit weight of the load, the ship's size and other factors as weather conditions, tide and swell, etc. Whenever the volume of goods to be handled is large enough to allow for a reasonable cost recovery of additional equipment, special devices can be adapted to improve the unit load or to shorten the cycle.

examples:

cements bags : 2 ton pallets built in the hold or on the apron: 40 ton/hour/crane. Pre-palletized bags: 80 ton/hour/crane, and more with spreaders. Cement in bulk can be handled at much higher speed.

exotic wood: logs up to 6-8 tons, handled by the piece with hydraulic clamps: 120 to 160 ton/hour/crane. Logs handled with slings; less than 100 ton/hour; only in daylight.

2.3- dry bulk traffic

agri-food products / fertilizers :

These low-density products are transported in bulk-carriers ranging from small cargo-boats (5,000 dwt) to cape-size bulk-carriers used for basic products (100 to 130,000 dwt ships).

Handling of export products is operated mainly with conveyors, whenever possible, with performances varying from 100 to nearly 1,000 ton/hour per conveyor, depending on ship size, port equipment, product characteristics and density, brittleness, and environmental and safety considerations linked to dust.

Ship to shore operations of import products require cranes and hoppers (20 to 35 ton capacity - 150 to 300 ton/hour), or elevators (400 to 1000 ton/hour) : two to three cranes per ship, or one elevator and two or more cranes on panamax and larger ships;

On the apron, small cargoes are generally loaded in trailers; large cargoes are carried through conveyor belts to warehouses or silos. High performance may be reached only if ship to shore operations are dissociated from commercial operations. Direct delivery alongside is the major cause of poor performance in bulk handling.

ratios :	small bulk-carrier, 1500 to 3000 t shipment:	100/120 ton/hour per crane : 2 cranes operated in one day
	from panamax up to cape-size, 60,000 t shipment:	1 elevator and 2 cranes : 1,100 ton/hour, 15 to 18,000 ton/day operated in four days

That performance may be reduced when operating multi-product cargo-ships. Some sticky, dusty or hard-to-handle products, such as manioc roots, impair the average performance. Brittle or dusty products may require lower handling rate for quality, safety and environmental purposes.

ore - coal : Export cargoes are usually loaded with conveyors; 1,000 to 2,000 ton/hour or more. Import traffic is handled with large gantry cranes geared with very large grabs: up to 1,000 ton/hour/gantry crane or with special devices. Same constraints, related to quality, safety and environment, may have to be taken into consideration.

Bulk-carriers ranging from the panamax to the cape-size: throughput: up to 15 to 20,000 ton/day

2.4- liquid bulk traffic

Generally, unloading performances depend on the size of the ship which provides pumps and energy. They depend also on its viscosity, temperature, and on safety regulations, for hazardous products. Most liquid carriers are operated within one day, whatever the size.

throughput: 300 to 1,000 cu m /hour, up to 10,000 cu m /hour and more for very large tankers.

3 – THE LABOR ISSUE

The staffing issue is one of the most complex and its successful settlement is often a key factor in a port restructuring process. Some indications are summarized thereafter

3.1- principles

Globally, transportation systems are increasingly productive, automatized and capital intensive. In all segments of the transport chain, direct employment tends to be reduced and more qualified. As far as ports are concerned, the situation where old public organizations integrated many or all port-related functions, which ended usually in a too large and poorly managed workforce, limited or poor level of services and high operating costs, is changing. Now, the private sector is increasingly associated in more efficient and competitive port operations, mainly through concessioning of infrastructures and privatization of services. The result is reduced staffing at all levels, higher qualification requirements and improved human resources management. Conversely, better performing ports contribute to foster trade and develop national economies.

Whenever possible, first addressing the overstaffing issue will facilitate the involvement of the private sector [2]. Since this situation is often the result of governmental policies considering port organizations as natural shelters for an unemployed and unskilled workforce, the same authorities have definitively a responsibility in helping dismantle the system and make sure that the consequences are properly cushioned. This supposes that adequate budgetary means and staff management skills are made available early enough in the process.

The concessioning process generally starts with industrial bulk and container terminals, because these activities are easily standardized and can be operated efficiently and with profit. Other fields of the port activity have often more severe problems and excessive staffing levels:

- The remaining port activities depend more on local conditions; they are subject to variations, due to seasonal effects, meteorology, variation in packaging and handling methods, low frequency of some operations etc.;
- with less economies of scale, operators of non unitized general cargo and miscellaneous bulks cannot easily invest in modern equipment and methods and these activities are less often reorganized;

[2] Some concessions have been granted even though this problem was not solved, concessionaires being requested to hire all existing staff and, if possible, solve the problem later. This results usually in high operating costs as long as the problem is not settled and, afterwards, depending on the financing scheme.

- the status of dock-workers placed under the responsibility of public authorities and hired intermittently by stevedores, once justified because of abusive practices, is still maintained in some countries; but, this organization, created to protect an undifferentiated low-skilled work-force in a context of weak labor regulations cannot evolve and does not correspond any longer to modern trends.
- In addition, some ports still maintain skilled workers and large workshops in order to undertake most or all of maintenance work; same thing as regards dredging;
- specific factors as social commitments of port authorities (health centers, housing etc.), inappropriate monitoring and tariffing procedures based on customs-like tax scales, are an additional cause of excessive administrative staffing.

The overstaffing issue is not easily addressed. Worldwide experience leads to recommend that the trade unions be brought to the negotiations table from the outset, when the reform program starts being devised. Actually, the most valid way to build confidence in the process while incorporating in it lessons of experience and market-oriented concerns is to bring together port users, port labor and port and maritime employers. The objective is to allow all stakeholders to share common concerns about competitiveness of port services, and a better understanding of how any weakening of this competitiveness would be detrimental to all, and in particular to the workforce which would be the first to bear the consequences of reduced economic activity, both inside and outside the port

3.2- proposed benchmarks

Port Authorities:

Some tentative benchmarks are proposed for Landlord Ports regulating a diversified activity, managing a proportionate public and private domain and not implied in commercial operations or services to ships such as pilotage or towage.

Size of the Port Authority	recommended staffing level
- small authority: a few millions tons:	about 50
- average port authority: 10 to 20 M tons:	from 150 to 200
- large ports: example: R'dam: 300 M tons:	1,100
More generally, an indicative ratio would be:	100,000 ton per staff per year, with large variations: . small ports require more than this proportion, large ports are more productive; . general cargo requires more staffing than bulk traffic.

Port operations

Containers: The recent study by Drewry, cited supra, as well as other comparisons between efficiently run container terminals, show a relatively constant productivity of about 1000 TEUs per staff per year, for a large array of yearly throughput, from 150,000 up to 600,000 TEUs. This includes all staff: operational, administrative and management.

Bulks: these operations require very few people: most automatized processes include large gantries and belt conveyors, that require only skilled drivers, a few supervisors and adapted crews for instant maintenance in hydraulics, electricity and automation. Additional staff are required occasionally, at the beginning, for preparation, and at the end, for trimming of remaining cargo, and for the cleaning of equipment.

Other operations (small bulks and general cargo):

In most cases, licensed port operators have a diversified activity: handling of various commodities, shipping agency, freight forwarding, inland storage etc., that helps them balance the level of employment. Usually, they try to limit the level of unemployment, specially when the old system of guaranteed salary for dock-workers has been rescinded, but they cannot face peak periods. That may occasionally lead to operate undermanned ships, hire temporary workers for low skilled positions, differ storage operations etc.

An average productiveness can be computed only as regards cargo handling (ship to shore), for a given commodity and handling technique. Some examples below show the large variation in productiveness [3].

Examples:

1) boxes in 2-ton pallets built in the hold (fruits, frozen goods etc.):

gang: total, 15 to 17 dockers, not incl.: transfer and storage crew, crane driver, maintenance staff;

productiveness: 50 ton per hour ➔ 3 ton /h / docker

2) pre-palletized boxes, handled with cages:

gang: about 13, including transfer, not incl.: storage crew / crane driver / maintenance staff;

productiveness: 225 ton per hour ➔ 17 ton / h / docker

3) exotic wood in logs, handled with slings:

gang: 12 to 15 dockers, not incl.: transfer and storage crew / crane driver / maintenance staff;

productiveness: 80 ton per hour ➔ 6 ton / h / docker

4) exotic wood in logs, handled with hydraulic clamps:

gang: 10 dockers, not incl.: transfer and storage crew / crane driver / maintenance staff;

productiveness: 140 ton per hour ➔ 14 ton / h / docker

nomic approach

Some modern ports have computed the global workforce related to the port activity, including handling operations, ship services and administration of both authorities and private sector: these figures relate to the port communities and are used in economic studies.

Some examples:

Rotterdam (1997): 300 M tons about 25,000 jobs

[3] The staffing level of a port system depends on its organization and the way labor regulation are enforced. In the old system with dock-workers under public management, the number of positions in a gang did not usually take into account the productivity of modern handling methods, which might result in a lack of gangs in case of peak activity, even though there were too many dock-workers according to modern standards.

Conversely, dock-workers having a low effective workload may look for overtime pay and try to double shifts. Night shifts, as well as week-end work, may require additional staffing for the same output, depending on existing regulations and the way they are enforced.

All (25) French Ports (1995): 275 M tons about 35,000 jobs

4- NOTE ON BERTH OCCUPANCY RATE AND QUEUING THEORY:

Ships are berthed according to available space and other constraints as number and size of bollards, number and location of main pieces of handling equipment, nautical constraints etc. For example, a 1000-meter quay can theoretically receive three large Panamax-type ships or four or five smaller ones. Only simulation systems could take these details into account. Analytical approaches require that a number of berths be specified in advance. It must be done by considering the length of ships commonly operated. Thus, if a terminal actually accommodates ships with various sizes and berthing space can be optimized, its real capacity may be slightly underestimated when using the methods described below.

4.1- berth occupancy rate

This rate is usually computed over a year, to include seasonal effects:

Cargo handling performance may be monitored by recording:

cumulated length of commercial operations alongside the quay v/s...
...available time over the given period

The optimal use of infrastructure might be best monitored with the following ratio:

cumulated length of call alongside the quay (including idle time) v/s...
...available time over the given period (365 x 24 h)

The difference accounts for all tasks and procedures to be performed when the ship is berthed, at the beginning or the end of the call. It also includes the consequences of the organization of work: restricted working time, lack of flexibility (shifts scheduled at fixed hours) etc., and the consequences of other constraints that apply to ships mooring or sailing out (tide, current, availability of pilots and tugs, swing bridges, locks...).

A distinction must be made according to the way ships are chartered:

Liner-ships have to comply with a precise schedule. If no berth is available at the time of arrival, the call may be canceled, the cargo shifted to another port or waiting for the next call. Thus, whenever competition exists between ports, the berth occupancy rate usually does not exceed 50 to 60 %. Higher rates can be seen when port facilities are saturated and there is no alternative, or when it is possible to schedule precisely a high number of calls; e.g., terminals dedicated to a single intensive traffic like short-sea Ro/Ro traffic or some private terminals operating on East-West trade with very intensive and well coordinated activity.

chartered ships are usually less affected by port congestion, depending on the nature of the cargo, the demurrage rate. Calls may be planned only a few days or weeks in advance. Their length may vary according to the nature and the size of the shipment. High berth occupancy rates can be observed, up to 80 %, sometimes more, generating significant waiting time.

Expanding the working period to 3 shifts per day and to the week-end, whenever possible, is the first and simplest way of improving this ratio.

4.2- queuing theories and simulations

Port congestion can be precisely assessed by using simulation models taking into account each significant step of the process. In some case, rough estimates can be obtained through simplifying methods. A common one is based on the computation of the ratio: waiting time/operating time, according to the berth occupancy rate and the number of berths [4].

Theoretical requirements are: a set of identical berths where an homogenous fleet of ships call on a first come first save basis. Arrival patterns and distributions of service times are approximated by a statistical law (Erlang distribution), simulating processes ranging from the random distribution (Erlang 1) to increasingly regular ones (Erlang 2, 3...).

• The average assumptions for a freighted traffic are:

- no distinctive pattern of calls ⇒ arrival at random,

- and various types of cargoes ⇒ service time at random.

- or homogeneous traffic ⇒ more regular service time, increasing order of the Erlang law,

• The average assumptions for liner traffic are:

- strict compliance with a schedule, i.e., a fixed distribution pattern of arrivals, ⇒ (Erlang ∞), practically Erlang law at 2 to 4th order.

- variation of service time depending on the nature and size of shipment. ⇒ increasing order.

This method is more suitable for chartered traffic and should not be applied to liner ships, as long as they do not wait. In such a case , the max berth occupancy rate depends primarily on the actual possibility to schedule calls evenly distributed.

This method represents correctly two phenomena:

- a very rapidly increasing waiting time when the berth occupancy rate rises;

- a very rapidly decreasing waiting time when the number of berths increases; dedicating an additional berth to an existing traffic improves flexibility and capacity to a much larger extent than the mere relative increase in the number of berths.

Generally, the maximum berth occupancy rate (corresponding to a low average waiting time) is lower with liners than with freighters.

nota: The Erlang function is implicit. It has been tabulated for some current cases or graphically translated. See in appendix 2 the table for E2/E2/N traffic (arrival and service time distributed according to an Erlang 2 law) and some graphs corresponding to usual combinations when arrivals are at random. The graphs give: waiting time v/s service time, according to the berth occupancy rate and the number of berths.

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[4] These methods, initially much developed for telecommunication purposes, have been extensively applied to port planning and design in the seventies. cf. UNCTAD Manual on Port Management 1976;

the number of interchangeable berths where the same ship can call.

synthesis of the proposed approaches;

mode	commodity	handling method	shipment's size	output per call	
unitized	containers	East-West traffic Gantry cranes	1,500 TEUs / call	85 to 120 TEUs/hour	11,000 ton/year/ meter of quay length
	containers	North-South traffic gantries and derricks	700 TEUs / call	60 to 90 TEUs/h	6,000 ton/year/ meter of quay length
break-bulk	cement:in/out	2 ton pallets	variable	120 to 240 ton/h	
	logs: unload.	hydraulic clamps	3 to 5,000 ton	300 to 400 ton/h	
	logs: unload:	slings	3 to 5,000 ton	< 300 ton/h	daylight only
	fruits	box on pallets	variable	42 to 55 ton/h	
	" " "	Pre-palletized	variable	225 ton/h	
unitiz.		*containerized*	*variable*	*700 ton/h*	
dry bulk	animal feedst.	elevators	30 to 60,000 ton	1,100 ton/h	
	" " " " " "	cranes	5,000 ton	300 ton/h	
	ore/coal	cranes	variable large	1,000 to 1,500 ton/h	
liquid bulk	crude oil	pumps	large (VLCC)	up to 15,000 ton/h	
	misc.	pumps	variable, small	300 to 1,000 ton/h	

Berth occupancy rate	Liner shipping	40 to 60 %	No delay; competitive traffic
	Freighted traffic	60 %, up to 80 %	Significant delays

Port equipment availability	Tractor – trailers	90 – 95 %	adapted fleet – adapted maintenance
	Gantries – cranes	80 – 90 %	adapted maintenance

Appendix n. 1: handling of boxes

Bananas, and other fruits, are packed in cardboard boxes, whose size and weight differ according to the final destination (roughly: 0.40 x 0.50 m; variable height ; 13,5 to 19.5 kg).

Three ways of handling these boxes are listed below, according to the resulting output:

i) boxes are handled in bulk; ships are loaded by building pallets on the apron and dismantling them in the hold (the cargo can be unloaded the same way). This is the traditional (and slow) way of handling boxes and bags, requiring a large work-force. On the other hand, the full capacity of reefers can be used (less broken stowage in old ships).

In average, a good handling throughput is about:	15 to 20 pallet/hour per hold,
i.e.:	720 to 960 box/hour,
or, with 19.5 kg boxes (48 boxes per pallet), about:	14 to 19 ton/hour;
<u>on three holds</u>, an expected throughput can be:	2,100 to 2,800 box/hour
or:	42 to 55 ton/hour.
With 20 working hours per day:	850 to 1,100 ton/day
or, with the same assumptions:	42 to 56,000 box/day

ii) pre-palletization is more and more widespread. Palletized fruits may be handled with cages holding two to four pallets at a time (when there is no more space in the hold to operate this way, each loading level is ended with several pre-slung pallets); cages are loaded/unloaded on the apron by one or two twin-fork front loaders, holding 2 pallets at a time; they are handled in the hold by four dock-workers using pallet-trucks. The average output, strongly depending upon organization of space and of operations, can be very high; at peak production, up to 150 pallet/hour per hold,

in average:	80 / 100 pallet/hour per hold,
with 80 pallets/hour/hold in average:	3,800 box/hour per hold
or:	75 ton/hour per hold,
<u>on three holds</u>:	11,400 boxes/hour
or:	225 ton/hour,
with 20 working hours/day:	4,500 ton/day;
or:	230,000 box/day,

iii) containerization: this is the last step of unitization; it is much more capital-intensive and not widespread. A 40' container holds 20 pallets. The handling throughput can be:

	15 cont./hour per crane,
or:	300 pallet/hour per crane,
or:	14,000 box/hour per crane
or:	280 ton/hour per crane

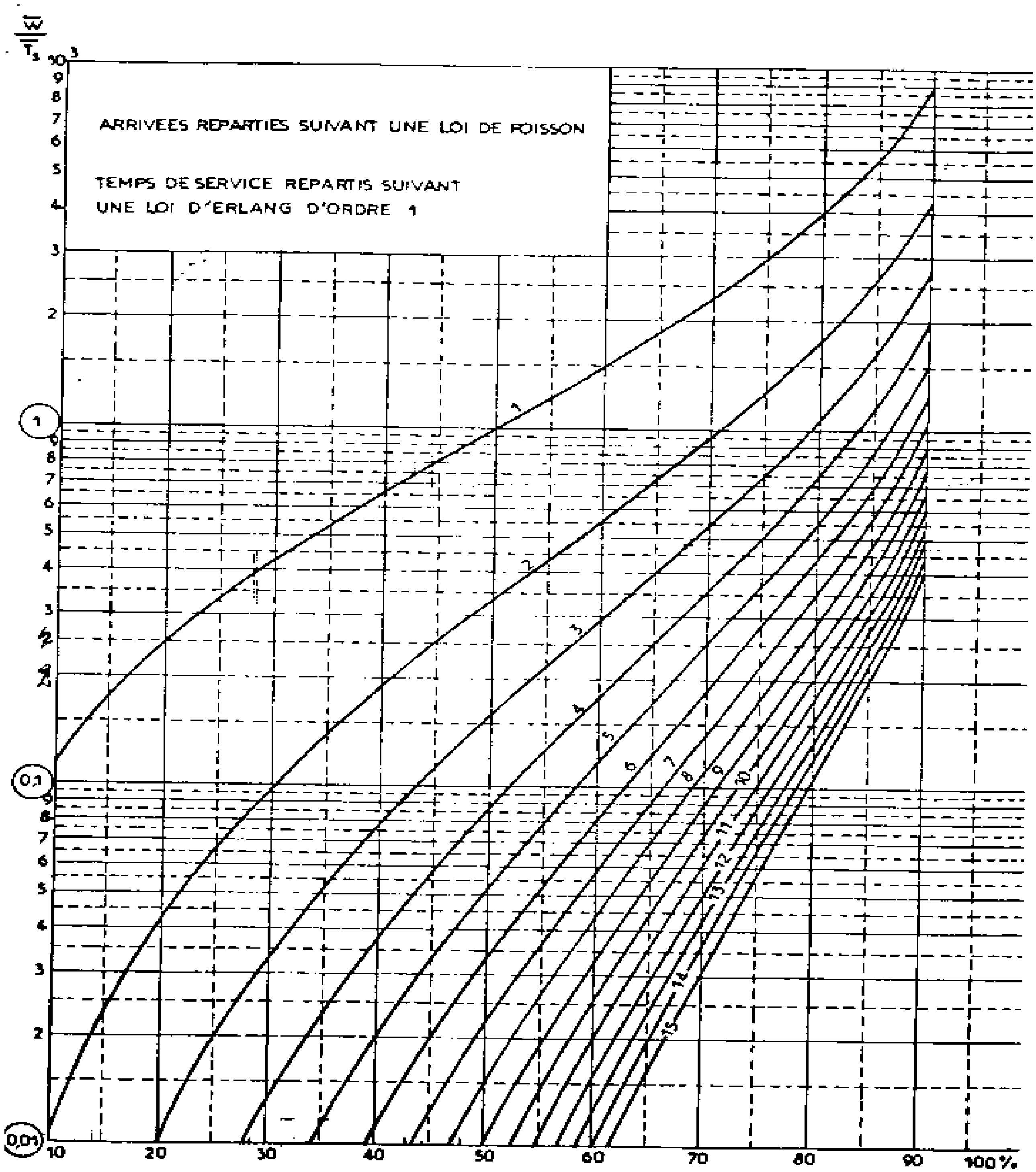
with 20 working hours/day: an average shipment can be loaded in less than one day.

iv) a fourth method exists, where boxes are loaded and unloaded in bulk. Special devices are used, based on conveyors: mobile ones, assembled for each call, or mounted on gantries (ref: Antwerp). Productivity vary between the first and second case and may be higher, depending on the level of equipment.

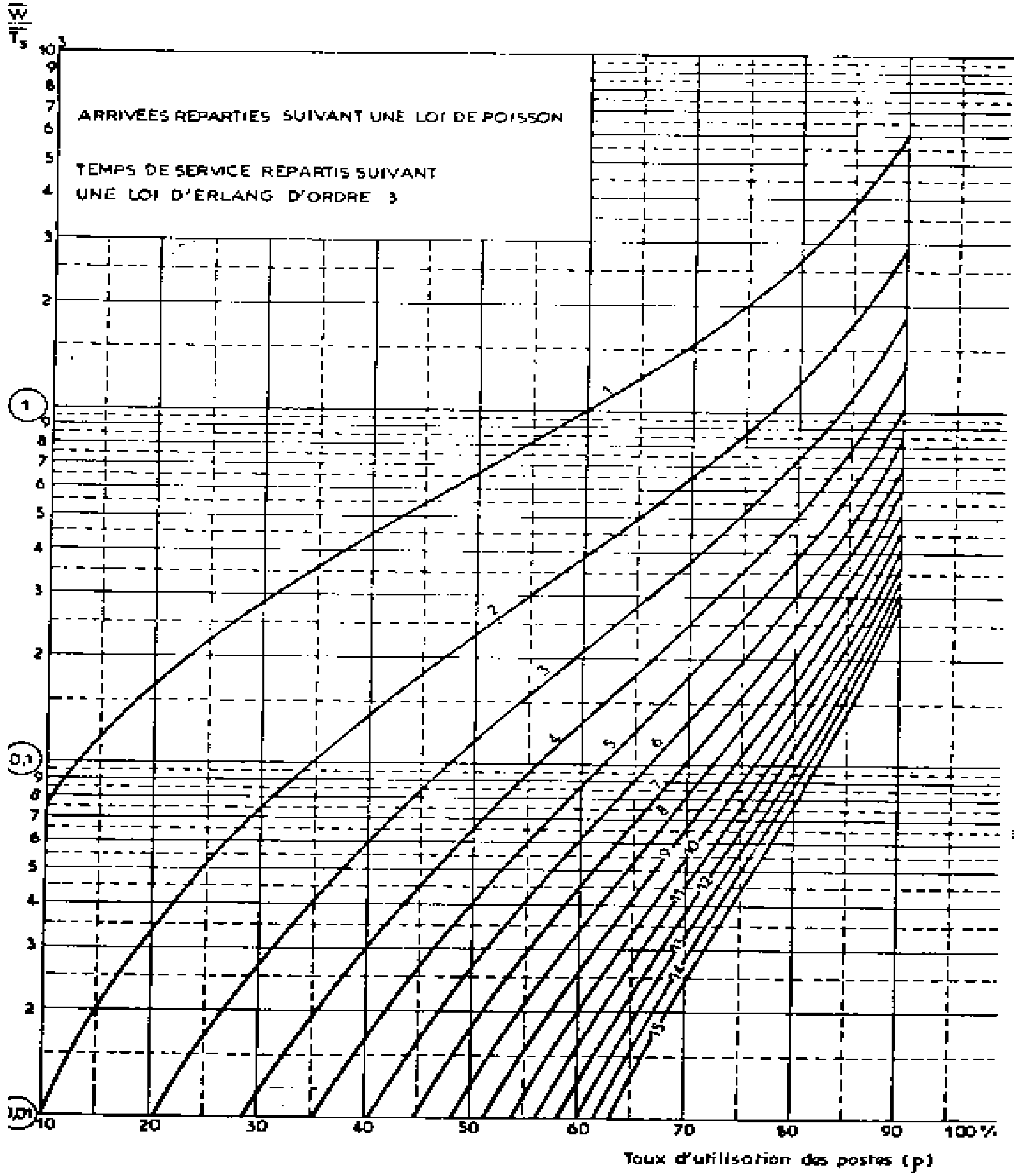
Appendix no. 2: waiting time and berth occupancy rate: table and graphs

Table E2/E2/N: CNUCED
Graphs: French Ministère de l'Equipement: Service Central Technique des Ports Maritimes et des Voies Navigables

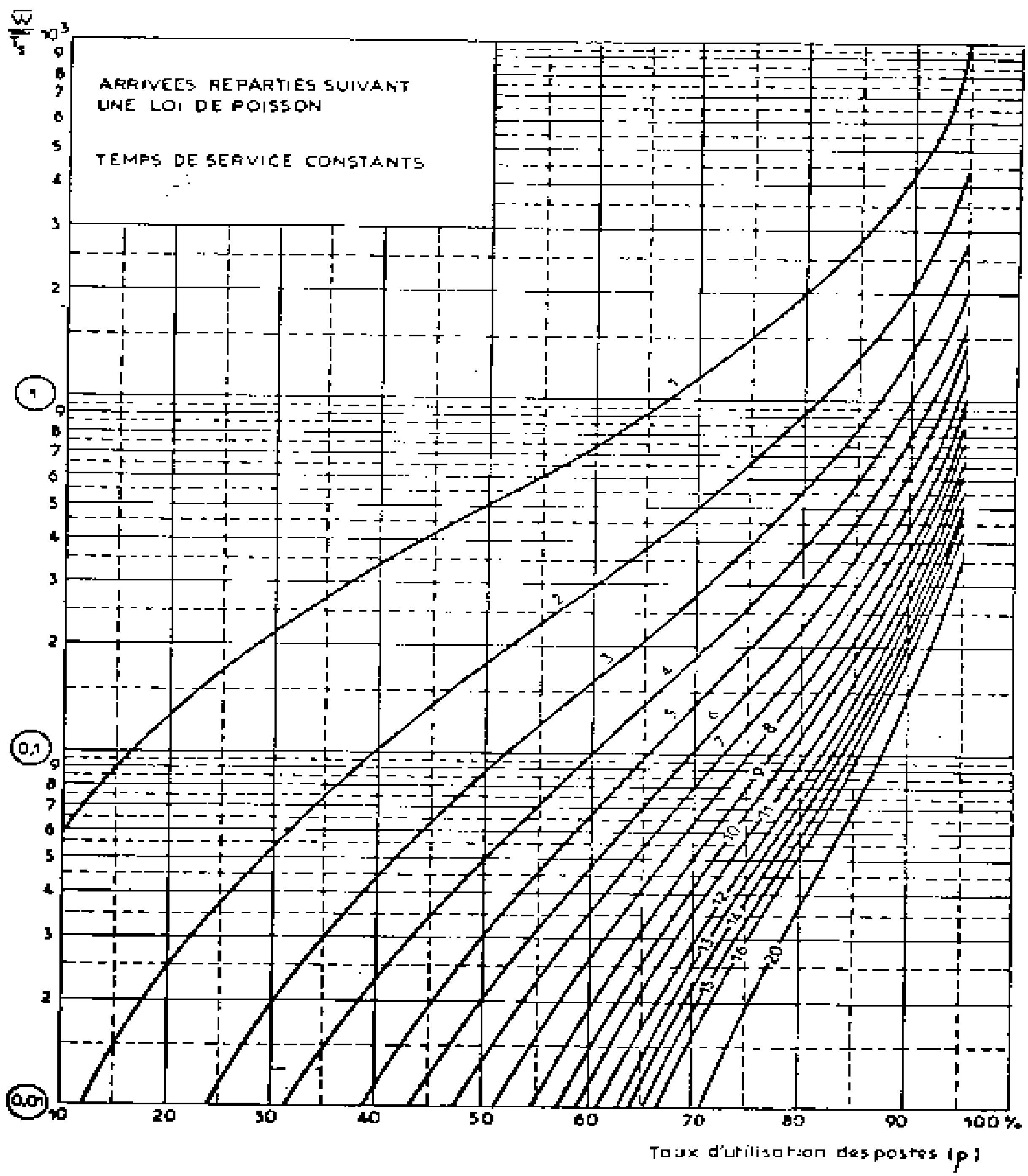
1): Arrival at random, service time at random



2): Arrival at random, service time Erlang 3



3): Arrival at random, service time: constant


ARRIVEES REPARTIES SUIVANT
UNE LOI DE POISSON
TEMPS DE SERVICE CONSTANTS
1
0,1
0,01
10
20
30
40
50
60
70
80
90
100 %
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
20
Taux d'utilisation des postes (ρ)

4): Arrival and service time : Erlang 2

Berth occupancy rate	*No. of Berths*		*Ratio:*	*Average waiting time*	*Vs. Average service time*			
%	1	2	3	4	5	6	7	8
10	0.02							
15	0.03	0.01						
20	0.06	0.01						
25	0.09	0.02	0.01					
30	0.13	0.02	0.01					
35	0.17	0.03	0.02	0.01				
40	0.24	0.06	0.02	0.01				
45	0.30	0.09	0.04	0.02	0.01	0.01		
50	0.39	0.12	0.05	0.03	0.01	0.01	0.01	
55	0.49	0.16	0.07	0.04	0.02	0.02	0.02	0.01
60	0.63	0.22	0.11	0.06	0.04	0.03	0.02	0.01
65	0.80	0.30	0.16	0.09	0.06	0.05	0.03	0.02
70	1.04	0.41	0.23	0.14	0.10	0.07	0.05	0.04
75	1.38	0.58	0.32	0.21	0.14	0.11	0.08	0.07
80	1.87	0.83	0.46	0.33	0.23	0.19	0.14	0.12
85	2.80	1.30	0.75	0.55	0.39	0.34	0.26	0.22
90	4.36	2.00	1.20	0.92	0.65	0.57	0.44	0.40