Long Term Optimization

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1 Terminal performance

The core business of a container terminal is the discharge and loading of object. A container terminal will also facilitate acceptance and delivery of containers and temporary storage of containers. Senior management of the terminal will be responsible for this process. One of the tasks of the senior management is to improve the core business. This can be achieved by improving the performance of the terminal. Improving the operational performance can also influence the financial results of the container terminal

This topic will describe methods that can assist senior management in improving the operational performance.

1.1 Reporting

A container terminal runs a 24/7 operation. Only the staff directly involved in the operation will be aware of the progress, disruptions and the constraints experienced during the operation. Staff not directly involved in the operation will have to be made aware of the progress of the operations and possible disturbances: The finance and administration department will have to send an invoice to the terminal's customers for the services rendered. The reports will also be used by management to manage the terminal by making use of *Key Performance Indicators* or KPI's. These are indicators measuring the level of activities.

It is important to report the delays in the operation and the respective reasons. The report should include which activities have been disrupted and the reasons causing the disruption. Costs for delays caused by object operators should be borne by that operator and should not be absorbed by the terminal. Following the completion of the operations of a ship, the system will create reports. Reports can also be created by command to verify the status of the operation, e.g. at the end of a shift. The system will calculate the various KPI's to allow the management to have a quick scan of the performance of the terminal. To allow the senior management to manage the terminal on KPI's, good reporting is the key and must be consistent.

1.2 Performance

Performance can be measured in quality and in quantity. Quantity will influence quality like quality will influence quantity.

Qualitative performance gives an indication to what extend the result, the discharge- and load operation of an object, is executed within the agreed tolerances of errors, accidents and damages. Quality can be measured in:

- Safety
- Damage prevention
- Efficiency

Quantitative performance gives an indication to what extend the result, the discharge- and load operation of an object, is executed within an agreed time period, using agreed resources. Quantity can be measured in:

- Production

- Productivity
- Utilization
- Service

1.3 Improvement

Structural improvement of the operation is one of the tasks of the senior management. This can be managed by making use of a set of KPI’s. No conclusions can be made based on only one KPI, it is the development of the KPI over time that will assist management in their improvement task.

Senior management must have issued procedures how they expect the terminal to be operated. This should ensure a safe and efficient operation. But work procedures will not suffice. The staff must know the importance of these procedures as well as realize why these procedures are in place. The staff must also be aware of how the equipment is to be operated and maintained.

This can be facilitated by training the staff. Training not only for the equipment they operate, but also for general safety issues and the procedures. Proper training will be the basis for an effective and safe terminal, minimizing damages and optimizing the performance.

2 Training

The basis of a good terminal is competent staff. This starts with the recruitment and selection of staff. The next step will be the training of the staff, followed by their remuneration. To ensure that staff remains up to date regarding the progress of the terminal and its revised or updated procedures, regular sessions should be arranged to update the staff on the progress of the terminal in its strive to improve.
Training can be used to improve the operation. There are a number of different types of training that can be offered to staff.

- Aptitude test.
  A training to assess if potential staff is suitable for a certain function prior to engagement. If a person is assessed as being not capable or suitable to perform a function, that person should not be hired for that function.
- Initial training.
  Following engagement of new staff, they require initial training consisting of the terminal rules, safety, and work methods and procedures.
- Functional training.
  Specific training can be organized to introduce the employee to the specific skills required for a proper execution of the various tasks involved for that function. This is for instance training on how to safely use and operate a quay crane or a terminal truck or another piece of equipment. This can also be training for the planners regarding ship stability or gate employees on how to manage agitated truck drivers.
- Refresher training.
  Refresher training is used to acquaint staff with updated methods, to train emergency drills or for remedial training.
- Retraining.
  Retraining is used to implement new tasks, new procedures or new types of equipment or new versions of software. This includes also training to prepare for promotion or management training.

Simulators can be used to assist in these trainings and tests. The advantage of using a simulator is that exactly identical situations can be repeated several times, no equipment will have to be made available and there will be no risks for damage to staff or equipment.
Well trained staff is the basis for an effective and safe terminal, minimizing damages and optimizing the performance.

3 Key Performance Indicators

Even though they are responsible, senior management will not be directly involved in the day to day operation of the terminal. To allow senior management to manage the terminal, reports will be produced. These reports will include KPI's, which, when studied over time, are a tool to assist senior management to manage the terminal. This chapter will clarify the different operational KPI's and explain their use.

3.1 Introduction

The performance of a container terminal can be expressed in qualitative as well as in quantitative performance, which will influence one another. One KPI will not suffice to describe the quality and quantity of a container terminal. It will have to be a combination of KPI's to describe the total productivity of the terminal.
A terminal that can only state that they can guarantee a performance of 30 container moves per hour per crane will give less trust than a terminal stating they can guarantee a performance of 75 moves per vessel with a quay occupation of 60% and stack-density of 75% considering a damage to cargo of less than 0,1% and less than 1 hospitalized casualty due to an accident in the last year.
It will be very difficult to compare the one container terminal to the other as all terminals are different. Either different in size, different in layout, different because of equipment or customers. The stack of PSA in Singapore is denser that the stack of CTA in Hamburg, which should reduce performance, PSA has more cranes per meter quay length which should increase performance. However PSA is a pure transshipment hub, while CTA is an import/export terminal which influences the stack and driving distance and last but not least, PSA is a manned terminal giving a higher degree of flexibility than CTA which is an automated terminal.
Despite the differences, a combination of KPI's gives insight in the performance of a terminal. This allows the terminal to compare their performance to other terminals.

3.2 Quality

Performance measure in quality gives an indication of the safety of the terminal and the carefulness with which the terminal treats the objects, their cargo and its staff. It gives insight in the number of casualties, fatal, hospitalized or minor casualties. It also gives insight in the level of damage prevention and cargo protection.

3.3 Quantity

Quantitative performance gives insight in volumes of containers per time unit or per resource per time unit. This can be expressed in a number of different categories, which will be described in detail below.

3.3.1 Production

The first category to express a performance is to measure the production of the terminal. Production is the output produced per time period. There are two types of production indicators:

- Traffic indicators:
  How many containers were handled by the terminal per day, week, month or

year?
Traffic indicators used to be included in annual reports to shareholders and customers and are a broad statement of the flow of containers through the terminal per time period. They can be measured in container or TEU. More details of the containers can be included like:

- Container status
  Import, export, transshipment, FCL, LCL or empty containers.
- Country of origin or destination
- Commodity class
  Reefer, hazardous, dry or a special container

Such a high degree of detail will give management the possibility to explain trends and take possible action to amend their targets.

- Throughput indicators:
  How many moves were made to handle the containers handled by the terminal per day, week, month or year?
  Throughput indicators give better insight in the efforts expended in handling the containers through the terminal per time period. This indicator can be calculated by adding the following throughput movements carried out during the various activities explained in chapter 4:
    - Ship throughput.
      Ship throughput quantifies the entire activity involved in loading and discharging vessels in terms of equivalent container moves. This includes the containers discharged and loaded, but also containers shifted on board and restowed via the quay. Every transshipment container move is counted, as well as erroneously discharged or loaded containers and hatch covers.
    - Quay transfer throughput
      The container yard throughput measures the number of container moves between the quay and the container yard. This throughput will always be less than the ship throughput as it excludes the shifters on board and the hatch covers. Some terminals temporarily store the restows in the back-reach of the crane in which case these restows will not be included.
    - Container yard throughput
      Container yard throughput is the sum of the movements that take place in the container yard, including the stacking of containers from the quay transfer, un-stacking to quay transfer, movements to and from CFS or customs and inspection area, as well as the in-stack shifters.
      The assumption is that the terminal uses separate equipment for quay transfer and stack. If the terminal operates a straddle carrier direct operating system, the (un-) stacking moves to and from quay transfer will not be included as these are counted in the quay transfer throughput.
    - Receipt/delivery throughput
      The receipt/delivery throughput measures the moves of containers related to the receipt of outbound containers from inland transport and the delivery of inbound containers to inland transport. This throughput will always be more than the containers passing through the gate. For inbound containers it is very likely that one or more containers in the stack will have to be moved to allow access to the target container. The higher the inbound stack, the higher the number of in-stack shifters.

The receipt/delivery throughput calculated in this manner does not necessarily give the correct amount of work of the gate area. In the gate area the number of vehicles handled is of interest. This does not however represent the gate throughput, because each vehicle will pass the gate twice, while not all vehicles will carry a container. Some vehicles will even carry two twenty foot containers.

The value of the throughput indicator gives a better indication in the total effort required to handle the traffic of the terminal. This will assist in estimating the required resources and the total cost of handling the traffic of containers.

3.3.2 Productivity

The second indicator for performance is productivity. This measures the efficiency of terminal operations. Productivity is expressed in terms of the quantity of production (containers or TEU) achieved per unit of resource or object per time unit. The productivity indicators are of particular interest to the management as they relate to the costs of operating the terminal: increasing the productivity will reduce the cost per unit and improve the profitability. Productivity can be expressed in gross working hours or net working hours. Gross working hours can include the time lost due to non-operational time like start-up of the operations and meal-breaks and idle times for equipment breakdowns and bad weather:

Net working time = Gross working time – (non-operational time + idle time)

A number of productivity indicators will be discussed.

1. Ship or vessel productivity

This indicator relates the volume of containers to the time the vessel was in port. This handling rate can be expressed not only in terms of containers handled (traffic) or container movements (throughput), but also in gross or net. The preference for this indicator would be the container movements over the containers handled.

Ideal would be if gross and net indicators would be close together as this would indicate hardly any loss due to non operational- or idle time.

This indicator gives no insight in the resources used for the operation. The more cranes and other equipment allocated to the vessel, the shorter the handling time and the higher the productivity values. Administrating this indicator over time will give insight in the continuity of the performance. Other aspects that may influence this productivity indicator are the planning, containers on deck versus under deck, large holds versus small stacks of containers over the whole vessel.

2. Crane productivity

The ship productivity indicators do not directly compare ship to ship or terminal to terminal because they do not consider the resources allocated to that operation: more cranes and other resources will result in a higher ship productivity. The crane productivity, which indicates the throughput per crane, allows a fairer comparison between vessels and terminals. Also this indicator can be expressed in gross and net production. They can vary considerably from service to service and ship to ship depending on:

- The ship design and construction
- The volume of containers discharged, loaded, shifted and restowed

- The distribution of the containers between bays and between on-deck versus under-deck
- The proportions of status and commodity classes

Comparison of the gross and net crane productivity for a particular ship's call can be very revealing about the efficiency of the operation. Large differences indicate that big improvements can be made by reducing non-operational and idle times.
More and more contracts between a terminal and its customers include production guarantees with minimum crane productivities at the cost of penalties.

3. Quay productivity

The quay productivity indicator relates the throughput (in containers or TEU's, but preferably movements) per berth (or meter quay) per time unit. Like the vessel productivity indicator, the quay productivity indicator produces a good measure, as this indicator fails to give an indication of the resources required for the work.
Quay productivity indicators can not be compared terminal to terminal. The one terminal may have handled a high proportion of small vessels, while another may have performed better because it only handled large vessels.

4. Terminal productivity

The terminal productivity indicator is similar in nature and intention to the quay productivity indicator, but applies to the entire area of the terminal. The terminal productivity indicator expresses terminal activity in terms of containers handled for every square meter of the terminal per unit time. Containers handled as in terminal traffic: the local containers discharged and loaded plus the transshipment containers discharged (transshipment containers to be counted one time only). Restows and shifts via the quay are not included as these occupy space on the terminal only for a very short period of time.
This indicator is usually expressed in TEU in stead of containers as a TEU is directly linked with a square area unit.
The calculated value of terminal area productivity varies from terminal to terminal and depends on the *dwell time*, the time the containers remain in the yard, the ratio of local to transshipment traffic and the type of stacking equipment in use.

5. Stack productivity

Related to the terminal productivity is the storage area, or stack productivity. The stack productivity is the number of containers (or better TEU's) handled per square meter of storage area per time unit. This indicator ignores the terminal area's dedicated to office, workshop, quay and other area's of the terminal. It only relates to the container yard (the gross storage area) or the container stacks (the net storage area).
Again indicators vary from terminal to terminal depending on particular the handling equipment used in the stack and the average dwell time of the containers.

6. CFS productivity

The CFS productivity indicators are expressed in containers (or TEU) per square meter per time unit and tons per square meter per time unit.

7. Equipment productivity

The equipment productivity indicator expresses the container moves per working hour for an individual machine or per machine of the fleet of that type of machine. It must be clear what is defined as a working hour.

- It can be assumed that equipment is available for work for 3 8-hour shifts per day for 7 days a week, ergo 168 hours per week. The working hour in this definition is reflecting the terminal working hour.
- In case not all equipment is required for all 21 shifts in the week, a more realistic definition could be the ‘allocated machine hours’: the total time the machine was requested by operations.
- Another definition might be the allocated time corrected for non-operational and idle times. This can easily be measured by making use of the hour meter fitted to the machine.

When comparing equipment productivity indicators (machine by machine, time period by time period or terminal by terminal) it is important to note that machine productivity is depending considerable on the activity for which a machine is employed, the status of the containers handled and the demand for that type of machine.

The equipment productivity indicator is very important when planning an investment for a logistic concept. Reviewing the performance of the various types of equipment is required to calculate the spare capacity of the terminal. It is also used to evaluate the performance of the equipment and decide on an improvement. An example of monitoring equipment productivity is given in figure 1.

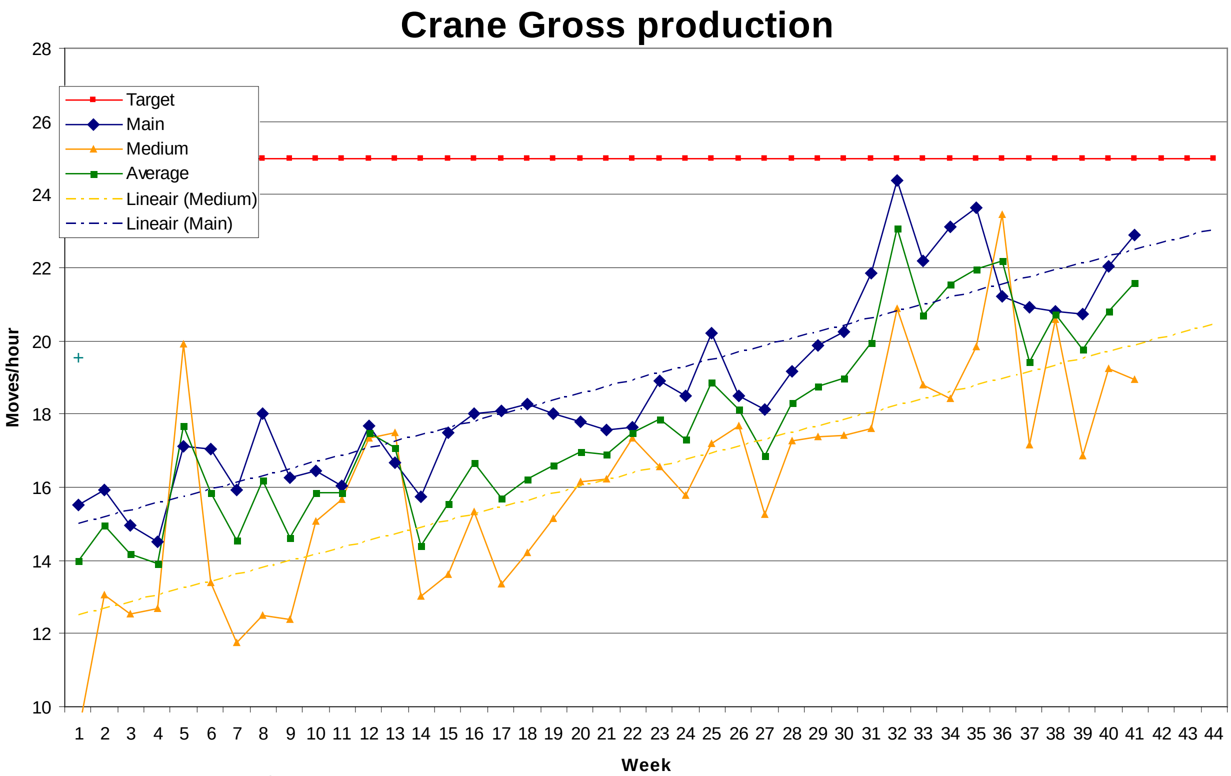

Figure 1: Example of Equipment productivity

8. Labour productivity

Labour productivity indicators relate container traffic or throughput to the number of people employed in the terminal.

Labour costs form a large part of the terminal costs and it is important to know what the productivity per man-hour is over a measured period. Like for equipment, it is important to decide what hours are to be used for this calculation. Equally important will be what personnel to include in the calculations:

- Total terminal staff
- Operational staff only
- Staff directly employed on a particular task

This makes comparison between terminals difficult. Therefore it should be clear what the definitions are of the calculated values.
It is also possible to calculate labour productivity per activity. This has a preference as optimization is often also managed per activity or service.

9. Cost effectiveness

The last category of productivity indicators is cost effectiveness. It brings also costs in the calculation. Cost effectiveness indicator is the total cost of the terminal per container or TEU handled (traffic) or movement (throughput) over a specified period. The difficulty here is deciding what costs to include in the total cost of handling. Normally the following costs are included:

- Costs for construction and maintenance of the terminal's infrastructure, calculated over its expected lifetime (e.g. 25 years), in proportion to the period being used for the calculation, (e.g. one year, ergo divide the total costs by 25 years).
- The total costs of the terminal's equipment, inclusive running costs and maintenance, proportional to the period used for the calculation.
- The total costs of employing permanent and temporary employees during the period used for the calculation.
- All insurance premiums and general overhead costs.

The cost per container movement gives insight in the cost to the terminal of every movement made. The costs per container or TEU are also used as a basis for setting tariffs. Cost effectiveness will also be used to manage improvement of the performance.

3.3.3 Utilization

The third category of performance indicators are those indicating the utilization of the terminals facilities, or how intensively the production resources are being used. Utilization indicators are usually calculated as a ratio, expressed in a percentage, between the actual use of a resource and the maximum possible use of that resource over a period of time. The most common utilization indicators are:

1. Quay utilization

The most common indicator of quay utilization is berth occupancy. Berth occupancy is calculated as the amount of available time in a given period that vessels occupy a berth. Not all container terminals identify berths; the quay is used flexibly, to consider the length of the vessels handled. In this case a length of quay of 200 to 250 or 300 meters is considered an equivalent to a berth. The berth occupancy is calculated by dividing the total number of vessel hours (the number of vessels calling at the terminal, multiplied by the number of hours each stayed at the terminal) by the number of berths or berth length along the quay.
High occupancy could indicate that the terminal's facilities are very attractive for vessel operators or slow container handling rather than effective utilization of the resources. An

acceptable utilization is 50%, but 60% is possible for terminals that have a longer quay. The longer the quay, the higher the flexibility of the terminal to allocate a berth to a vessel. Terminals with a longer quay can have a utilization of 60%.

2. Stack utilization

Storage, stack or yard utilization is the indicator that compares the number of slots occupied in the stack with the total number of available slots or design capacity. The design capacity is easy to calculate: the sum of the design capacity of all blocks. Per block the design length in TEU times the width in TEU times the height per TEU. The slots occupied can be filtered from the terminal operating system.
A stack utilization of 65%-70% is the maximum to allow a normal operation. In case the utilization will be higher than 70% a normal stack operation will not be possible and the number of stack-stack moves will increase drastically. This will also pollute and disrupt the build-up of the stack causing further disruption of the operation and reducing the total productivity.
In case the utilization will be close to 70% for longer periods of time management should take action to reduce in particular steps the dwell time of the containers. If such action cannot be taken, management should find ways to increase the stacking area. This will usually result in large investment to either increase the stacking area and procurement of additional equipment, or, in case of increased stacking height, modification of equipment. In case of a low utilization, management may consider alternative use for some area's of the yard.

3. CFS storage utilization

A similar approach as with yard occupancy can be used for CFS storage utilization. Each day, usually at the same time estimate the areas occupied by cargo and compare this to the available space for storage.

4. Gate utilization

Gate utilization is the actual passages of trucks over a period versus the maximum possible. Smooth and rapid processing of trucks delivering or picking up containers is very important for efficient operations. Gate utilization demonstrates the risk of delays at peak times. The gate utilization factor is an average and will therefore not show the peaks and lows. Terminal operators will use statistics to identify the peaks and to facilitate sufficient lanes and staff to ensure a smooth transit of trucks also during peak hours.

5. Equipment utilization

The equipment utilization is calculated for any item or type of equipment. It compares the time the equipment was effectively deployed to a specified period, or the time it was actually used versus the maximum time that it could have been used (machine hours versus possible machine hours).
Equipment utilization data for a type of equipment gives useful information of the adequacy of the volume of that type of equipment. A utilization of 40% indicates that there is an overstock of that type of equipment, while 80% suggests an additional demand for more equipment. These utilization indicators need further study, as low utilization may also indicate high peaks, while high utilizations can conceal a backlog of maintenance.

3.3.4 Service

The forth category of performance indicators are those indicating the quality of the service supplied to the terminals customers

To ensure that the terminal is competitive, service indicators must be developed to monitor the services rendered. This can be investigated by developing market surveys, asking the customers for their opinion. It is wise to also develop indicators that allow the terminal to measure service levels by themselves and to compare these with the outcome of the (regular) market surveys.

The most common utilization indicators are

1. Ship turnaround time

One of the most important indicators of service to ship operators is the ship turnaround time, the total time spent by a vessel in a port for a given call. This can be averaged out for all vessels of a ship operator or per trade and vessel type.

The vessel turnaround time consists of 4 specific periods:

- Waiting time, the time between the arrival of the ship at the port and the start of the moving of the ship to the berth. Delays may be caused by waiting for pilot, berth still occupied, waiting for tide. This waiting time is normally spent at anchor.
- Berthing time, the time taken to proceed from the anchorage to the terminal and safely berth the vessel.
- Service time, the time the ship will be at the berth, between being moored and unmooring.
- Sailing delay, the interval between leaving the quay (unmooring) and leaving the port.

Ideally the ship turnaround time should be only a little longer than the berthing time. To reduce waiting time, terminals and their customers have agreed berthing arrangements and agreements like berthing windows. If a ship arrives within an agreed timeframe, the ship will have a guaranteed berth with minimal productivity and resources.

It is wise to identify different trades to monitor the ship turnaround time as usually a specific type of vessel is dedicated to a trade. Container volumes also differ per trade as does the distribution of the containers over the vessel. All these factors will influence the turnaround time and will be specific for each trade.

The terminal should aim to ensure that vessels are operated and can leave within the ETA-ETD interval set by the ship operator in it’s master trade sailing schedule.

2. Truck turnaround time

For road vehicles a similar approach is taken. The truck turnaround time means how much time does it take a truck to deliver a container to the terminal, or collect a container. This service indicator is the time between gate-in and gate-out and includes the following steps:

- Waiting time at entry.
- Service time at reception, the time required to process documentation.
- Transit time to gate-in.
- Service time at gate-in, inspection of truck and container.
- Moving to interchange area.
- Waiting at interchange area, for discharging container from truck or load on truck.
- Moving to gate-out area/lane

- Service time at gate-out.
- Leaving time to exit terminal.

Especially the actions gate-in and gate-out are important as these times will be recorded for transfer of risk and responsibilities.

3. Rail service indicators

Rail service indicators are less straightforward than vessel and truck turnaround times. Train arrival and departing times are often decided by the railway company to fit its time tables, wagons are held in separate area’s and regularly shunted from the one train to the other and trains are often scheduled to be operated during non-peak hours. This is why a turnaround time as indicator is not useful.
Therefore often the proportion of trains leaving the terminal within the times advertised in the rail timetable is calculated. The terminal should aim for a 100% score.

4. Operational dwell time

Operational dwell time for discharge containers is the dwell time sum of the period between discharge of the container and the initial advice of the terminal that the container has been discharged and stacked and that customs clearance can start and an agreed period for customs clearance.
For outbound containers the operational dwell time is the average actual dwell time corrected for the dwell time which is agreed between the terminal and the customer.

5. Equipment downtime and availability

The earlier mentioned service indicators measure the levels of service supplied to the terminal’s customers. Service indicators can also be developed for internal use. This is often the case with the maintenance organization. These KPI’s like downtime and availability, are discussed in topic 12, maintenance management.

4 Activities

The services the container terminal supplies to its customers are offered by executing one or more activities. The total of these activities form the flow of the container through the terminal. Depending on the logistic concept used by the terminal, these activities are connected and the one activity is dependent on the next, as is indicated in figure 2 below. This is where queues can form. Queues are an indication of a bottleneck that can be investigated to start improvement. In this chapter the various activities are identified and explained.

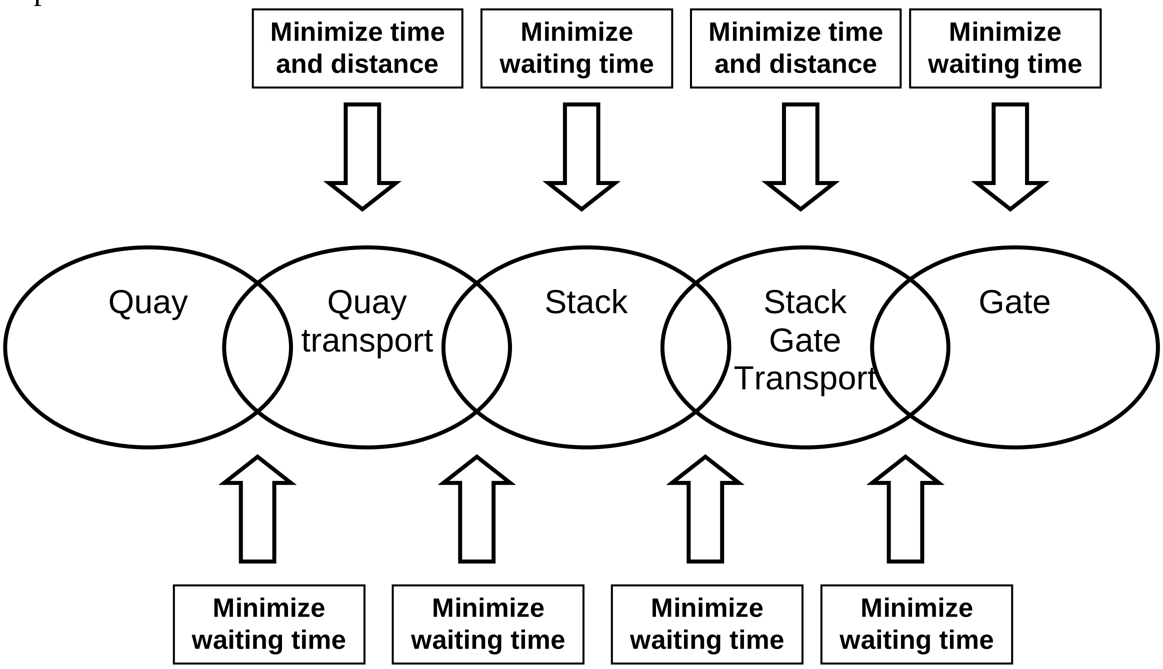

Figure 2: Connecting activities and dependencies

4.1 Services

There are three main services provided by the container terminal:

- Container arrival
  Containers arrive by road, rail and inland waterway, as well as from feeder and deep-sea. There are a number of activities involved in this service, which are described in this chapter.
- Container storage
  Following the arrival of the container at the container terminal, the container will be temporarily stored until it leaves the container terminal again. A number of activities can take place, including the CFS and empty depot activities. These will also be described in this chapter.
- Container departure
  Containers leave the container terminal by road, rail and inland waterway, as well as from feeder and deep-sea. There are a number of activities involved in this service which are described in this chapter.

Whether containers arrive for import or export does not really matter when the activities are considered, be it that activities are opposite and the container flow is mirrored.

4.2 Ship operation

The ship operation consists of movement of containers from the ship to the quay and vice versa.
For the inbound container the ship operation starts with the crane operator positioning the spreader of the crane on top of the container. The spreader will be locked to the container and the crane operator can lift the container and move this to the quay, where it is landed on the ground or on the chassis which will arrange transport to the stack. Once landed, the crane operator will unlock the spreader, hoist the empty spreader and move back to the vessel to pick up the next container. This completes one *discharge cycle* of the crane.
For the outbound container the operation consists of attachment of the spreader to the container as it stands on the quay (either on the ground or on a chassis). The crane operator will lift the container and move to the vessel. When the container is over its stowage position, the crane operator will land the container in its assigned stowage position, after which the crane operator will move the spreader back to the quay to load the next container and complete the *load cyc*le.

4.3 Quay transfer operation

The quay transfer operation consists of movement of the containers from the quay to the stack area and vice versa.
Inbound containers will be moved from the quay to the landside section of the stacking area. This includes lifting the container by the transfer equipment from the quay surface beneath the crane, or by the crane landing the container directly on a chassis. The transfer equipment then follows a prescribed route to the stack area dictated by the system. The transfer equipment stacks the container in the storage position or stops at an interchange position to allow the stacking equipment to lift the container from the chassis and deliver it to its storage position.
For outbound containers the movement is mirrored, with the exception that outbound containers have a preferred storage position on the waterside of the stacking area. Also the route followed by the equipment that arranges the transfer differs from the inbound route. Storing inbound containers on the landside and outbound containers on the waterside of the stack will prevent traffic congestions of public road traffic with terminal traffic and reduces the risk of accidents.

4.4 Container yard operation

Two different operations can be identified in the container yard or stacking area: the moving of containers within the stacking area and the movement of containers to and from CFS for stuffing- and stripping activities.
When there is dedicated equipment for the stack, to only lift containers to and from the quay transfer equipment, the stacking and un-stacking activities are part of the container yard operations. In case the quay transfer equipment directly enters the stacking area to also lift containers from and into the stacking area, these movements are part of the quay transfer operation.
Stacking area activities are also the movement of containers from one stack position to another stack position to reach a target container that is to be moved to the quay or gate.

Another activity in stack operation is the movement of containers from the stack to the CFS for unpacking or stripping activities after which the (empty) container is returned to the designated empty container storage area. Alternatively, the activities involved with moving of an empty container to the CFS for stuffing and subsequent return of the full container to the stacking.
By order of the custom authorities and by request of the customer, the container may be moved to an inspection area, and subsequent return to the stack. Occasional movements may also be requested for damaged containers which need repair, and their subsequent return to the stack.

4.5 Container receipt and delivery operation

The activities involving the delivery and receipt operation are depending on the modality taking receipt of the container or delivering the container. When the modality is a barge and the barge operation is the deep sea quay, the operation will be the same as it is for the deep sea vessels and feeders.
When the modality is a train, the container is lifted from the stack and is positioned on the transport to the rail terminal. If the equipment arranging the quay transfer operation directly enters the stack, the equipment may deliver the container directly at the rail terminal.
On some terminals, the public trucks may enter the terminal to travel alongside the stack to receive a container from the stack operating equipment. Some terminals have an interchange area, where containers are delivered to a truck. The truck, having received the container, will then move to the gate area. In the gate area the container is inspected, the seal number is verified and the documentation is checked.
There are equivalent activities for containers being delivered to the terminal by road, rail or inland shipping transport.

5 Improvement

Studying the various KPI's and the activities to which they refer, suggestions can be made to improve the performance of the terminal. Even though one activity will influence the other, it is wise to disconnect the activities and study improvements per activity. This will allow easier management of the changes and their effects. The changes can be procedural as well as technical or a combination of the two. The following chapters will suggest a number of changes per activity.
As explained in chapter 3, staff should be trained regularly to keep them focussed and aware of the processes of the terminal. Especially with changed procedures and changed equipment, training of the staff is essential to allow the suggested improvements to succeed.

5.1 Ship operation

The ship operation is executed by cranes. With the development of world trade, vessels grew larger and larger. This also resulted in the terminals needing to invest in larger cranes to allow the cranes to also reach the outside of the vessels.
Larger vessel meant also larger volumes of containers to be discharged and loaded, while the port stay of the vessel was not always extended. The investigations to increase the performance of the crane led to a number of improvements that can be introduced, technical as well as procedural:

1. Increased speeds.
   The distance the trolley had to travel when discharging and loading the vessels increased on the big vessels, as did the distance for the spreader. This led to developing cranes with increased speeds for hoisting and trolley travelling.
2. Twin lift.
   Larger vessels led to larger volumes of containers. Crane manufacturers and spreader manufacturers found a solution to carry two 20ft containers in one hoist, called *twin lift*, leading to a reduction of the crane moves. This development also necessitated the crane manufacturer to design a crane that could cope with the increased hoisting weights.
3. Tandem lift.
   Following the twin load development, crane manufacturers investigated the possibility to also lift two 40ft containers in one lift, so-called tandem lift. This development resulted also in tandem-twin-lift, or four 20ft containers in one lift, considering the increased lifting capacity. One crane manufacturer is also investigating triple lift, three 40ft containers in one lift.
4. Second trolley.
   Using two trolleys on a big crane allows a main trolley to travel up and down between the vessel and the landing spot where the containers are temporarily stored for pick up and delivery to the quay transport by the second trolley. This will disconnect the discharge or load cycle and reduce the distances the main trolley has to travel. This also allows for (semi) automation of the crane.
5. Dual cycling.
   When studying the cycle of the crane, it can be noted that the crane is not lifting a container during half the cycle. If the crane would pick up a container for loading, directly following the landing of a container on the quay transport, and moving

back to the vessel to stow the container in its final position, the cycle would be more productive and performance would increase. This change means a change in the process and procedures and requires also a change of the mind-set of the planners. It will also result in an improvement of the occupancy of the quay transfer equipment.

6. Decrease waiting time.
   Another way to increase the productivity of the crane is to disconnect the dependency between the crane and the quay transport. If the crane could land the container on the quay, called the transfer point, the crane would not have to wait for the quay transport to arrive. The quay transport can pick up the container at the transfer point and bring this to the stack. This could mean that the logistic concept of the terminal would have to be reconsidered, resulting in large changes in procedures, layout and equipment with the related substantial investments.

5.2 Quay transfer

Where on a container terminal the discharge and loading process is performed by gantry cranes, the quay transport is executed by a variety of equipment. The management and shareholders of the terminal will have selected a logistic concept for the terminal, straddle carrier, lift truck, terminal truck/chassis combination or and automated concept. This will also influence the layout of the terminal and the stacking area. Despite this variety of equipment some general directions for improvement can be given.

1. Increase the speed of the transport.
   Increasing the speed of the quay transport will result in a shorter travel time from quay to stack and an increase of the potential productivity. Careful consideration should be given to the effects on safety. In case the safety is at risk, this option should be cast aside.
2. Reduce the travel distance.
   A reduction of the travel distance will have the same result as increasing the speed. This may result in additional changes:
   - Changed layout.
     Changing the existing layout will have major consequences and requires investment. Consequences are related to changing procedures, the lining and signing on the terminal and additional training for staff.
   - Changed procedure.
     Travel distance can also be reduced by transferring the container from the crane to quay transport in the back reach of the crane instead of between it’s legs. In this way, the quay transport does not need to travel alongside the vessel until it has a position to break away to the stack and can take the shortest route to the stack.
3. Increase of equipment.
   An increase of the equipment will result in more containers being transported per hour, therefore also improving the performance. This will result in, not only additional investment, but an increase of operational costs as well. If management decides to increase the fleet of terminal truck/chassis from 5 to 6 per crane, the investment is perhaps us $100,000.- per crane. Management must also consider that more staff is required for such an operation: if the terminal has a 5-shift operation and we consider 10% loss because of sickness and holidays, this would

mean an addition of 5.5 truck drivers per crane. This will increase the operational cost drastically.

4. Automation
   Automated quay transport has a very constant performance without any peaks or lows. Therefore performance is very reliable. The related investment is high, however it also has a saving in operational expenses. Considering 5 terminal truck/chassis and a 5 shift system, a saving of 25 truck drivers per crane are possible.

5.3 Container yard

As being the case with the quay transport, the container yard can be operated with a variety of equipment. This is depending again on the logistic concept selected by the terminal management and the terminal shareholders. Deciding the logistic concept is of major importance as this concept will be the manner in which the terminal will be operated for a long time. Changing the logistic concept will have major effects on equipment, because of investment in new equipment, procedures, because of changed working methods and staff and because of required training.
Each type of equipment will have it's own characteristics and improvement potentials. Technical improvements are mostly developed by manufactures of this equipment. Following are a few suggestions of how to improve the performance of the yard.

1. Decrease waiting time.
   An increase of the performance of the stack is to disconnect the dependency between the equipment operating the stack and the quay transport. If the quay transport could land the container on a transfer point, the quay transport would not have to wait for the stack equipment to arrive.
2. Increase the stack capacity.
   In case of continued high stack occupancy, where customers do not have the possibility to decrease the dwell time, management can consider an increase of the stack capacity:
   - Increase the stacking area.
     In case the terminal does have space available an increase of the stacking area can be considered by adding on or two blocks for import and export. This will require the development of additional area and investment of additional stacking equipment.
   - Increase the stack height.
     Stack capacity can also be increased by increasing the stacking height. This will also result in the stack equipment to be modified and increase the movements the stack equipment will make per container traffic.
   - Changing the logistic concept.
     A stack operated by a straddle carrier will require more space than a stack operated by an RTG. Changing the concept to RTG will increase the stack capacity, but will require investment.
   - Increase stack-block size.
     For an RTG concept, the block size can be increased from 5 containers wide to 6 or 7 containers wide. This will require modification of the equipment. Also management must study if the road- and isle ways do not suffer. Alternatively road- and isle ways can be organized for one-way traffic only to create space for expansion of a block.

- Increase equipment.
  Lastly additional equipment can be introduced to ensure quick dispatch of the quay transfer equipment or quick delivery to public road transport.

5.4 Gate area

Based on design calculations by the terminal management, a decision is made how many gate lanes are required. Such calculations can only be made if the customers of the terminal are willing to advise their cargo breakdown per modality. Statistical information is also required to identify the peaks. Considering these, a decision can be made how many gate lines are required. This should be a careful consideration as it will not be easy to increase the number of gate lanes once the terminal is up and running. There are a number of steps in the gate process as explained in chapter 3 which can be studied. Decisions to improve can be:

1. I-Card and Pre-announce.
   Truck drivers may identify themselves at the gate-in with a pass containing details of the identity of the driver. If their arrival and purpose for the visit has been announced, the system will recognize the driver and the driver will receive instructions where to go to pick up or drop off a container. Such a system also requires the cooperation of the customs authorities.
2. EDI.
   The gate process is the order process in which the instructions of the customers of the terminal are being managed. Customers send instructions to the terminal gate and staff informs them who will deliver which container for which vessel, or who will pick up a container. By making use of EDI the staff involved with processing these instructions can be reduced and performance increased.
3. OCR.
   Optical Character Recognition is a system that can identify the container number automatically. This will release the terminal staff from their task to note down the container number and reduce the risk of typographical errors. OCR is often combined with an automated gate.
4. Automated gate.
   In an automated gate, cameras will record the condition of the truck and the container and the license plate of the truck. This is often combined with the I-Card, EDI and OCR. Staff will only be required to inspect the customs seal attached to the container.
5. E-seal.
   E-seal is still under development but will be a development for the future to perhaps an unmanned gate where the customs seal will be verified electronically.

5.5 Customer awareness

Studying the various performance indicators may well lead to conclusions that improvement is possible for vessels, staff or information of the customer. If conclusions can be made on the basis of a number of consecutive reports, the customer can be advised accordingly with the request to act, explaining that this will improve the performance of the terminal. An improved performance may well lead to a cost saving. This cost saving can partially be used to offer tariff reductions to the customer as an incentive. Below are a few of the items that may stand out in reports and KPI’s.

1. Ship construction.
   In case of delays on the same vessel are reported for a number of consecutive calls, a study of the reason of the delay may lead to conclusions relating to the construction of the vessel. Examples are the crane spreader not properly fitting in the hatch cover or cell guides that not allows the crane to lower the container at maximum speed. The customer may have received reports from other terminals, in that case the customer may wish to correct the situation.
2. Staff quality.
   In case the reports indicate a disrupted operation for each call of a vessel being managed by a certain central planner, while other central planners have none, the customer may be interested to arrange additional training to improve the quality of the central planner.
3. Dwell time.
   In case the utilization of the stack is over 70% over a longer period of time, the performance of the terminal will be affected. Dwell times may differ customer to customer. In such a case the customer with the longer dwell time can be approached to convince them to reduce dwell times.
4. Information quality.
   Information supplied by the customers to the terminal will not always be correct, not even if this is supplied in EDI format. This leads to the terminal requiring staff to correct the information provided by it’s customers. Building an inventory of these errors will give the terminal insight in the costs involved with correcting the errors. Management of the terminal can suggest to the customer a quality improvement project of the information flow. This may result in less mistakes in messages, reducing the required staff, allowing a financial incentive for the customer in case a quality level is reached.

6 Simulation

6.1 Design

A container terminal will be run as a commercial company. Decisions have to be made concerning the layout, the logistic concept, the terminal operating system and the required equipment. From these decisions, capital costs and operational costs can be calculated. Comparing these costs with the container volumes derived from the potential customers will lead to a pricing model.
Constructing a new container terminal requires a substantial investment. The decisions regarding layout, logistic concept, operating system and equipment cannot be taken lightly.
The layout will be depending on the available area. The logistic concept depends on for example the expected operational cost and preference of shareholders, as does the selection of operating system and equipment. The risk involved with not selecting the optimum scenario for the design is high. A simulation scenario will assist in deciding logistic concept, layout operating system and equipment. Simulation allows the various designs and selections to be compared to optimize the layout, the logistic concept, the operating system and the equipment. The various options can than be compared on financial result to allow a founded decision.
Costs for a simulation are only a fraction of the total cost of a new container terminal. It is therefore advisable to include a simulation assignment in a budget for the design of a new terminal.

6.2 Improvements

Some of the suggested improvements in chapter 5 require substantial investments, while the management will not have a guarantee that such improvement will bring the desired effect of an improved performance.
A simulation model can compare the old situation with the suggested improvement to assist in the decision to implement the improvement. It will also give a better view on the effects of the improvement for the other activities, resulting in identifying the next bottleneck in the operation. This allows a better preparation of the organization for the implementation of the improvement. This can be equipment or a new system release.

6.3 Safety

Simulation can also be used for investigations in accidents. Next to the subjective statement of the staff involved in an accident, simulation will add an objective view to the investigation in the cause of the accident
The same scenario can be played a number of times to find the cause of an accident and conclude actions to prevent such an accident from re-occurring.

6.4 Training

Large machines are operated on a container terminal, costing a lot of money. These large machines handle containers that may carry expensive goods. New staff must be trained how to use this material with the risk of damage to equipment or goods. This risk can be prevented to make simulator models of the equipment to allow the new staff to familiarize themselves with the equipment.

The terminal in a simulation environment will also allow staff managing the operations to train and familiarize themselves with the operating system without any risk for damage to equipment of containers.

7 Automation

Automation of a terminal will not necessarily increase the productivity. It will reduce the terminals flexibility; however it will give a very constant performance without any peaks or lows. This will increase the reliability of the terminal.
Automation requires a large investment, however the organization of the terminal will be small compared to a fully manned terminal. The savings, depending on the wages of the staff, can be substantial.

7.1 Ship operation

Technology is available to fully automate the crane, however this is not used. As yet always a crane operator will be in the crane to attach the spreader of the crane to a container. Several stages of the crane's cycle can be automated:

1. A two trolley operated crane.
   The second trolley of a crane designed with two trolleys can be fully automated. The crane will have a platform where the operator of the main trolley will land the container. The unmanned second trolley can pick up the container from the platform and land this on the quay or on the quay transport.
2. Semi automated crane.
   The crane can be automated such that after the operator has picked up a container, the crane will automatically hoist and travel the trolley to land the container on the quay or quay transport. Alternatively, just before landing, the operator can take over.

7.2 Quay transport

There are two systems available for automated quay transport. One is for automated straddle carrier (ASC), the other for automated guided vehicles (AGV). The advantage of the ASC is that the ship operation is disconnected from the quay transport, while the AGV and crane are connected. An AGV manufacturer is investigating a lift AGV. The crane will land the container on a frame. The lift AGV can maneuver under the frame, lift its platform to pick up the container from the frame and drive to the stack. In this manner the crane process is disconnected from the quay transport process.
Sensors assist in maneuvering the automated equipment in the correct position to pick up or receive the container.
The automated, unmanned, area should be well separated (by fences) from manned area's to prevent staff of third party personnel to enter these area's.

7.3 Stack

Especially a rail mounted gantry crane (RMG) is suitable for automation as the wheels are fixed on rails preventing the RMG to move sideways. An RMG can also operate a higher stack density than other equipment like RTG. An RMG operated stack requires a higher infrastructure investment because of the rails, which are not required for an RTG. An automated RMG stack can be combined very well with automated quay transport.
It must be prohibited to enter an automated stack while the terminal is operated, unless special permission is granted.

7.4 Gate

In an automated gate, cameras will record the condition of the truck and the container and the license plate of the truck. This is often combined with the I-Card, EDI and OCR. Staff will only be required to inspect the customs seal attached to the container. This is also explained in chapter 5.

8 Finance

8.1 Cost versus benefits

When investigating an improvement, part of the investigation should be the cost-benefit analysis. This analysis the costs involved with the investment for the improvement should be calculated and compared to the benefits. The earn-back period should not be too long, while social aspects must also be considered.
The earn-back period is different in each individual situation. The interest levels will also play a role in such a consideration in connection with net present value calculations. The social aspects may be related to reduction of the labour force, per crane team or total.
Example:
The terminal traffic is 1,000,000 containers per annum with 10 cranes. A growth is expected of 10% over a period of 5 years, 2% per annum. A new crane costs us$10mln. A technical enhancement of the crane costs us$150,000.- per crane and the cost of capital is 10% per annum.
What should the management of the terminal do?
10% increase of traffic means that the terminal traffic will increase to 1,100,000 containers in 5 years time. Considering the cranes productivity of 100,000 per annum, this would necessitate the procurement of a new crane from day one, an investment of us$10,000,000.-.
Alternatively the 10 existing cranes would receive an improvement, increasing the productivity to 110,000 and costing us$150,000.- per crane or us$1,500,000.-.
Postponing the procurement of the crane for 5 years would save 10% or us$5,000,000.-, which compensates the additional investment of us$2,225,000.-, (us$1,500,000 plus (10% * 5years * us$1,500,000)).
Additional factors are that the staff will not increase for another 5 years, restricting the operational expenses and the risk that the growth does not materialize is taken out of the equation.

8.2 Cost of automation

The cost of automation is substantial, be it that they are small compared to the total investment of a new terminal. An automated terminal does however require a longer period for testing, increasing the pre-operational running costs. This again can often be included in the investment cost.
Savings induced by automation can be substantial; especially in those area’s where labour is more expensive. Operational staff works in shifts, possibly a 4 or 5 shift system.
Automating the quay transport with a 10 crane operation reduces the number of terminal truck/chassis combinations by 50 or 60 (depending on 5 or 6 trucks per crane).
Considering a 5 shift operation, the total operational staff will reduce by 250 – 300 persons, resulting in a considerable reduction of the operational expenses.