Port **Logistics**

Process Control System for Automated Container Terminals

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1 Automated Container Terminals

The transportation of goods in containers has shown a massive growth over the years worldwide and is still expanding. Modern container terminals build the bridge between the different modalities which are used in today's container transportation. Loading and unloading equipment is combined with storage areas in order to link different types of transportation. The modal split, the relative expected volumes for each of the modalities, determine the design of modern container terminals. Advanced terminal management software is required to facilitate an efficient and cost-effective operation.

Quay cranes are the bottleneck in the process of loading and unloading deep sea ships. For this reasons all other operations need to operate such that a continuous operation of the Quay Cranes is ensured.

Modalities

Depending on the location of the terminal, it must be possible to load and unload containers from:

❐ Deepsea ships,
❐ Feeders, Coasters,
❐ Barges,
❐ Trains (railway),
❐ Trucks (road).

At modern container terminals, all of these modalities come together. Container flows must be uncoupled by using buffers. Also storage times at the container terminal must be kept as short as possible to shorten the delivery times of goods from supplier to end customer.

Containers are stored in a storage area and transferred between the storage area and the subsequent modalities.

Container types and usage

Typical container sizes are 20ft, 40 ft or 45 ft. Special containers like reefers, tank containers, dangerous goods, open top containers, out of gauge, flats, bundles, pile-up and pile-on containers must also be handled.

Ship to shore AGVs   ASCs   SCs Trucks/trains

Transfer points
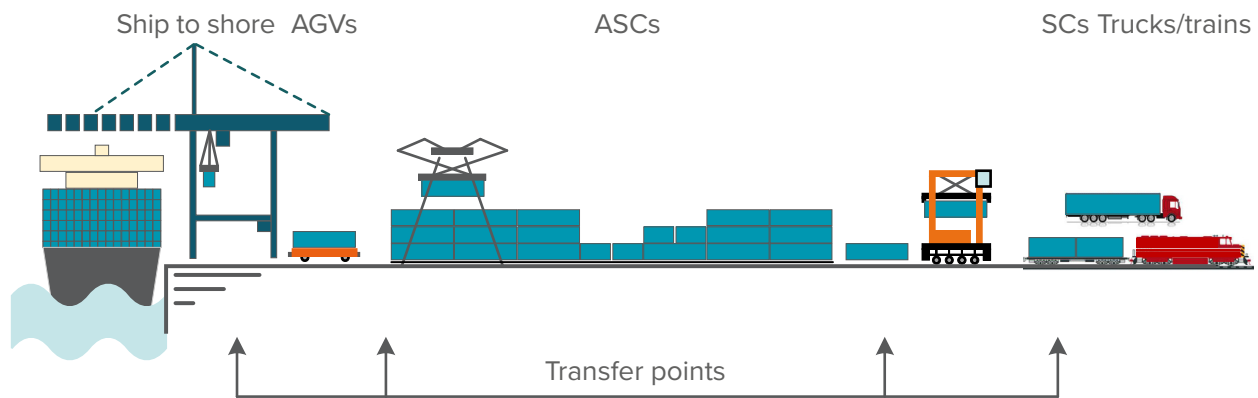
2 Equipment

Automated terminal operation can be achieved by using high effective and efficient container handling equipment: QC – Quay Crane , AGVs - Automated Guided Vehicles, ASCs - Automated Stacking Cranes, SCs - Straddle Carriers, TTs - Terminal Trucks, MTS - Multi Trailer System, RC - Rail Cranes, RF - Reefer Cars, Reach stackers and Forklift trucks.

Manned and unmanned equipment
Generally speaking, unmanned equipment can be used in situations in which containers are provided in a standardized way. Special measurements must be taken to ensure a safe and smooth operation. Areas in which unmanned equipment is in operation are inaccessible for other traffic. External flows of containers (like ship-to-shore, truck loading) are therefore still handled by manned equipment.

Quay Cranes
Quay Cranes (QCs) are used to load or unload deep sea ships, feeders or barges. Typical Quay Cranes can pick up or put containers on the quay in the middle between the rails, or at the back, on the landside of the crane. The area at the back is used

as a temporary buffer used for storage of items for handling the ship and hatch covers. Large ships can be loaded/unloaded simultaneously by several QCs in parallel.

Quay Cranes can be manned by a crane driver or operate automatically. Down at the landside, another employee or an automated system is PCS for Automated Container Terminals responsible for container checking and guarding the process.
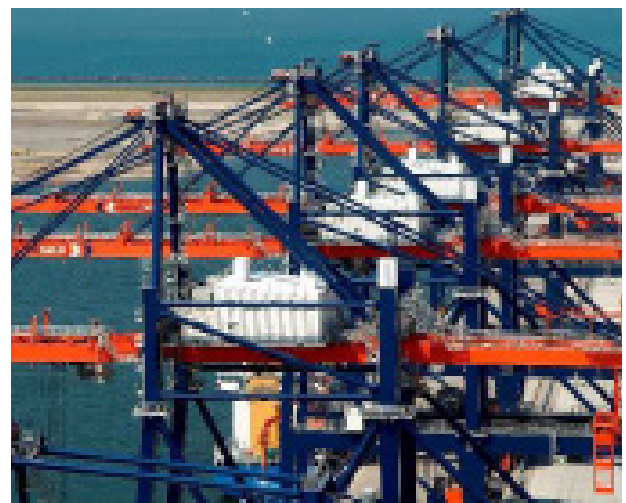
Automated Stacking Cranes (ASC)

Automated Stacking Cranes are unmanned cranes, used to stack containers in special ASC storage areas. The advantage of ASCs is their fast, unmanned operation.

Automated Guided Vehicle (AGV)

Automated Guided Vehicles are used for the automated transport of containers from the quay (QC positions) to the ASCs sub stacks and vice versa.

Because on safety reasons, AGVs are allowed to drive in predefined areas only, separated from all other traffic.

AGVs usually determine their position by means of a grid of electronic transponders which are mounted at certain distances in the surface.
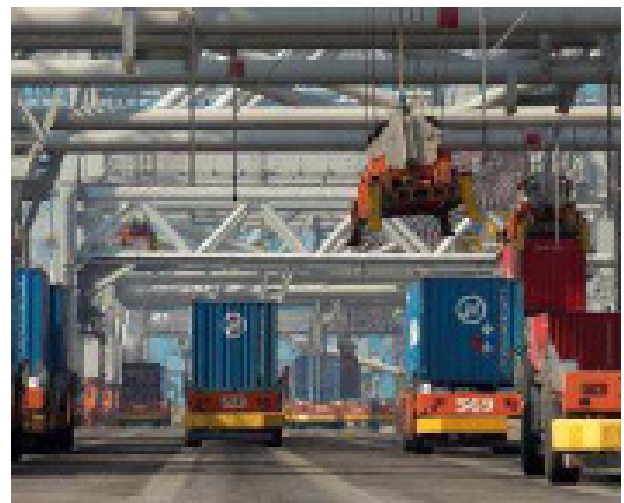
3 Storage

An automated container terminal can be divided in several operational areas in which containers can be stored. Storage locations can be: SC-stacks, ASC-stacks, On-Wheels (odd-size containers), Inspection buffers, Emergency buffers or special areas. As stated earlier for safety and practical reasons storage locations and operational areas for the several types of equipment are separated. Trucks cannot go into the operational SC area. SCs are not allowed in the ASC or AGV area. Transfers of containers between the several types of equipment take place at transfer points.
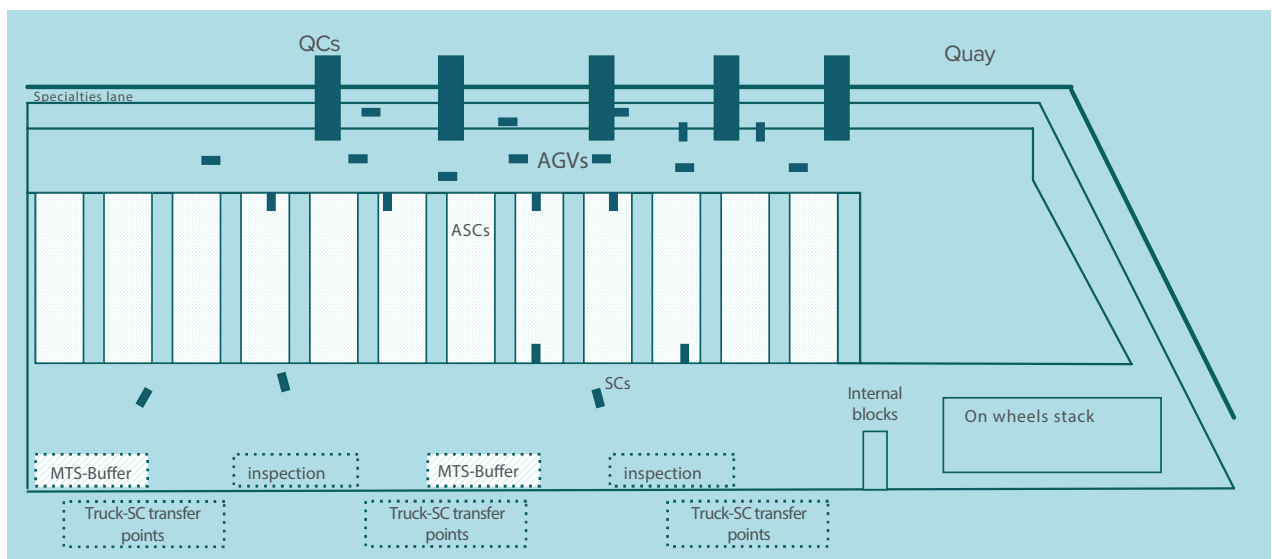
Storage - Automated Stacking Cranes

Containers can be placed very close to each other in ASC sub stacks. This depends on the accuracy of the ASCs and the dimensions of the spreader.

Reefer containers can be stored in ASC sub stacks at dedicated positions. Here power connections are available to hook up the reefers. Special lanes are available for personal to reach these locations safely.

At the Waterside Transfer Point, locations are defined on which Automated Guided Vehicles can park within reach of the ASCs. ASCs can transfer a container from or to an AGV.

In normal operations the Waterside Transfer Points are suitable for a seamless transfer of containers to and from the sub stack.
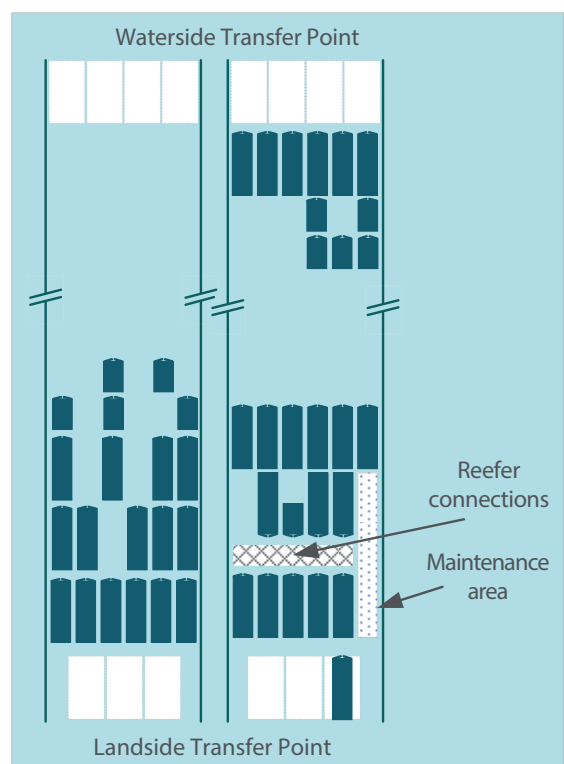
4 PCS - Process Control System

The Process Control System is designed for high throughput automated container terminals, equipped with ASCs and AGVs, combined with manned equipment. Operations is based on the logistical decoupling of waterside container flows and landside container flows. Containers are stored in an automated stack. AGVs are routed automatically by PCS for optimal performance of the ship to shore operation. ASCs operations and stack usage are automatically optimized to support QC and AGV operations at waterside and to serve SC's operations at landside. Operators can use an extensive set of screens and functions to configure and influence the execution of the container handling process.

The critical success factor for the PCS performance is the optimized support for the QC operation. PCS controls operations to remove containers from the QC area when the QC is unloading the ship, and to supply the requested containers in time for ship loading operations. PCS uses moments where the system is not fully occupied to reorganize the automated stacks. The containers are moved to the location where the destination ship is planned. This reduces the time to transport a container to the QC at moments it really matters, "Quay Cranes must never have to wait".

Overall Process Control
The PCS is responsible for the coordination and execution of all terminal operations involved. PCS issues transportation orders to the AGVs and ASCs, which are carried out automatically by the equipment. PCS also provides working orders for manned equipment, such as Straddle Carriers (SC's), Multi Trailer Systems and even Reefer cars.

PCS System context
A Terminal Operating System consists of several systems. The TOS controls the complete terminal, e.g. EDI Messaging, Truck Gate Control, Quay Planning, Ship Planning.

TOS			
Inter Terminal Communication System			
Planning & Administration System (PAS)		Computer Aided Ship planning (CAS)	
Proces Control System (PCS)			
Manned Equipment STS	Automated Equipment AGVs	Automated Equipment ASCs	Manned Equipment SCs / TTs / RCs

PCS concentrates on the execution of the operation. PCS receives commands from the other systems and reports back its status.

PCS has communication links with the equipment. Links to manned equipment are used to issue commands to the operators. On Straddle Carriers a list of container movements is displayed. QCs are connected to PCS to inform PCS about their position, movements, position of the trolley, container dimensions. PCS instructs the QC driver about the work area for the QC. The QC receives its loading or unloading commands with accompanying container data directly from TOS.
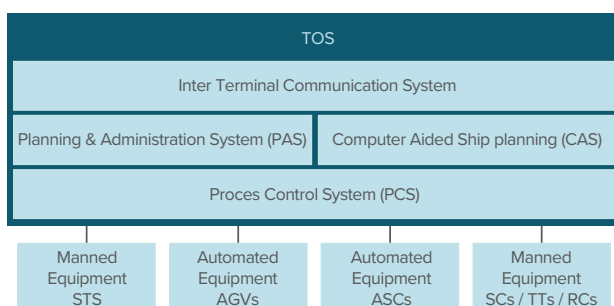
Every 2 seconds PCS calculates the optimal AGV routing for all AGVs. The interaction between systems, i.e. QC-AGV, AGV-AGV, AGV-ASC and ASCSC is also coordinated by PCS.

ASCs have their own control system. PCS issues commands to the ASCs to store and retrieve containers from the stack.

5 PCS System user interface

The PCS system consists of several components, each with specific tasks. Operation and control is done via PCs with mouse and keyboard. The PCS system is a server application with thick-clients connected to it. PCS provides the graphical interface to the users of the system. The graphical user interface can be used split into two parts: Command & presentation interface, with several screens, a menu structure, buttons etc. for user interaction, and the Alarm Panel, in which alarms, exceptions and events are displayed.

The PCS applications support the user in the following roles:
⌐ Coordination of the operational process execution
⌐ Execution of waterside activities
⌐ Usage of AGVs, ASCs
⌐ Execution of landside activities
⌐ Usage of manned equipment SC's, TT's and RC's
⌐ Technical maintenance support; alarms, messages, fuel levels, working hours registration etc.

Button bar with choice of screens and applications.

In the sequence as shown in the Button-bar, the user can choose screens to be displayed and used:
⌐ ASC screens
⌐ ASC Stack overview screens
⌐ Container information
⌐ AGV screens
⌐ AGV refuelling
⌐ AGV Maintenance
⌐ Examiner
⌐ ASC area Transfer Points
⌐ Manned Equipment (SCs, MTS)
⌐ QC Overview
⌐ Progress monitor
⌐ Quay Overview
⌐ Queued commands
⌐ Reports
⌐ Alarm Panel
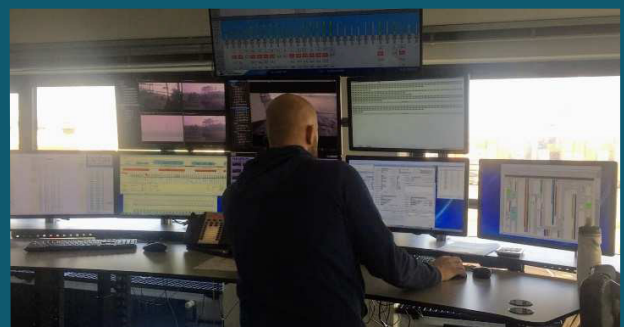
6 PCS Operational functions

PCS keeps a list of planned work orders and executes these orders. PCS receives its orders from the TOS (Terminal

Operating system). For PCS following aspects are important:
- Split container movements in subsequent movements of equipment which is available for operation
- Planning in time of container movements
- Work load distribution within each type of equipment and usage of equipment given the planned work load
- Control and adjustments in case of problems, errors, changing of plans or operator interaction
- Achieve maximum terminal performance

Progress monitor

The progress monitor is a PCS application which can be used as a dashboard. The most relevant information is displayed in overview screens.

Progress monitor gives a quick outline of the operational status of the container terminal. The screen shows the number of equipment available for operation (ASCs, AGVs, SCs, etc.). The free room in ASC stacks is displayed; the availability of Transfer Points at ASC sub stacks and the work load (%) and filling (%) of ASC sub stacks.

PCS Progress monitor.

Examiner

Part of the PCS application is the Examiner. It displays the current operation status in a graphical way. In a plant overview screen equipment movements are displayed in real time. Users can view the overview screen, zoom in, request details of equipment etc.
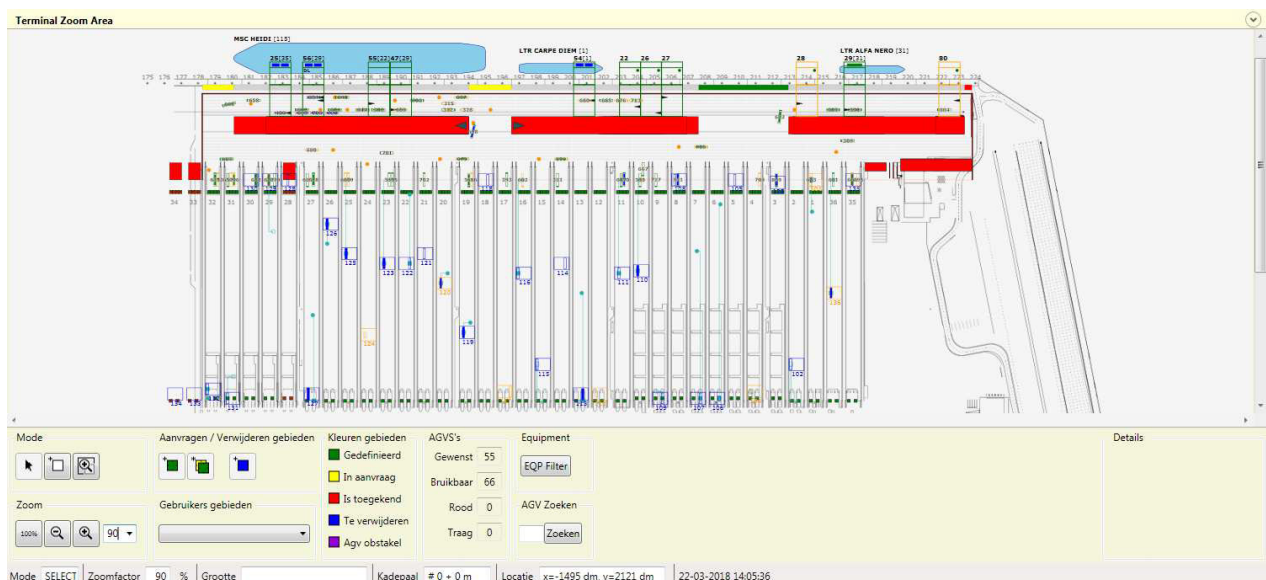
Example screen for Examiner

In the Examiner screen, the Operator can see detailed information about AGV and ASC positions. The display consists of several layers which can be switched on or off for better visibility. E.g. show routes on/off, show AGV claims on/off, show equipment numbers on/of etc.

Transfer Points - Waterside Quay overview

In the examiner a user can zoom in to the Waterside Quay. Here the actual positions of QCs are displayed. As QCs move, their Transfer Points for AGV transfer move with them. PCS automatically adapts the floating Transfer Points and recalculates the driving routes for the individual AGVs instantly. Operators can claim several area's around the Quay area where AGV routes are blocked. In this way operators can manipulate the automatic routing algorithms of PCS to control the individual AGV routes.

The claims and release of areas in which AGV can ride is a major instrument to influence the effectiveness and performance of AGV operation.
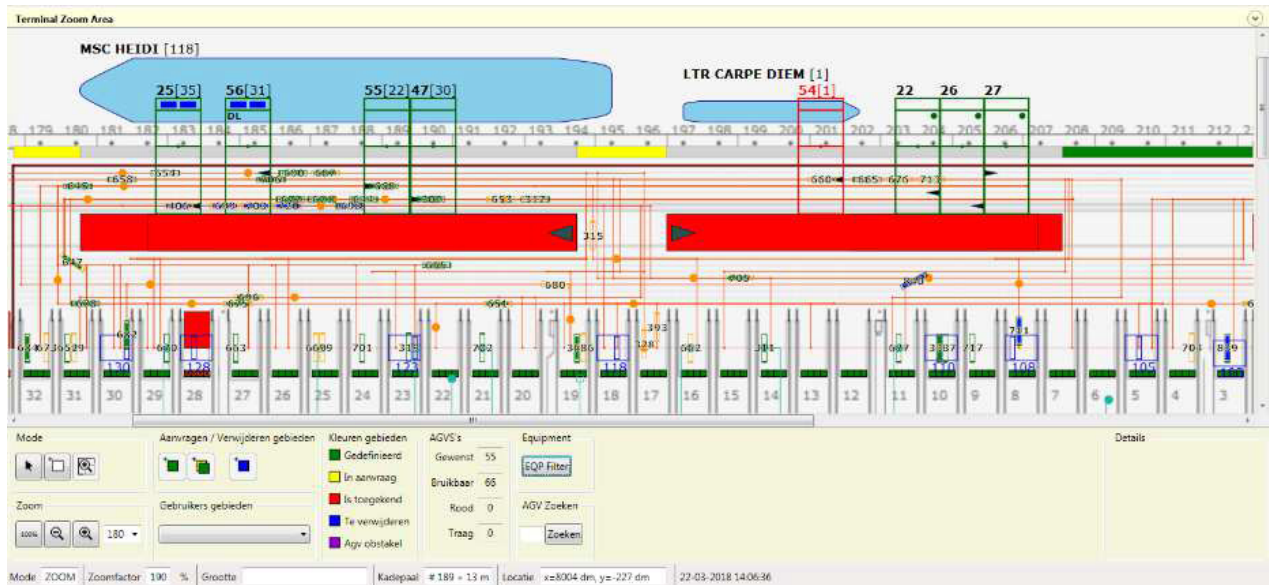
Example screen for Quay overview

In the Examiner screen, the Operator can see detailed information about AGV and ASC positions. The display consists of several layers which can be switched on or off for better visibility. E.g. show routes on/off, show AGV claims on/off, show equipment numbers on/of etc.

AGV planning & routing

AGV planning and routing depends for a great deal on how waterside operation at the QCs is organized. Operators can influence how to optimize this process. Operators have functions to:

❐ **Setup road patterns for AGVs, with priorities**

With PCS, the operator determines which QCs are to be used and on which part the QCs will be active. Based on this information, PCS generates suitable road patterns for the AGVs. During operation the operator can adapt priorities and the number of AGVs assigned to each QC.

❐ **Assign AGVs to particular activities**

Priorities of container movements and optimization of driving distances and travel times are continuously being recalculated to make the optimal assignment of AGVs to the given work load.

❐ **Traffic control of the AGVs**

AGVs are autonomous and have built-in safety functions to prevent collisions and accidents. PCS makes traffic arrangements in such way, that traffic incidents between AGVs cannot occur. Stop-and-restart behaviour of AGVs is avoided by PCS as much as possible.

Parallel to the quay different types of lanes are defined to arrange AGVs traffic: QC-roads, (underneath the QC); Highways for AGV supply to the QC areas and AGV discharge from QC area; ASC-ASC traffic; roads to refuelling area and maintenance area.

ASC Waterside Transfer Points

An important way for operators to influence and optimize the overall terminal performance, is to release or block Transfer Points at the ASC sub stacks, where AGVs can or cannot dispatch their containers to a particular sub stack. Although PCS uses its own algorithms to fill ASC sub stacks in the most optimal way, PCS depends on information from the TOS system for future forecasts when and where containers will be retrieved from the sub stack. In practice TOS might not always have this information available. Operators can direct containers to sub stacks close to quay parts where they know the containers are going to be retrieved soon.
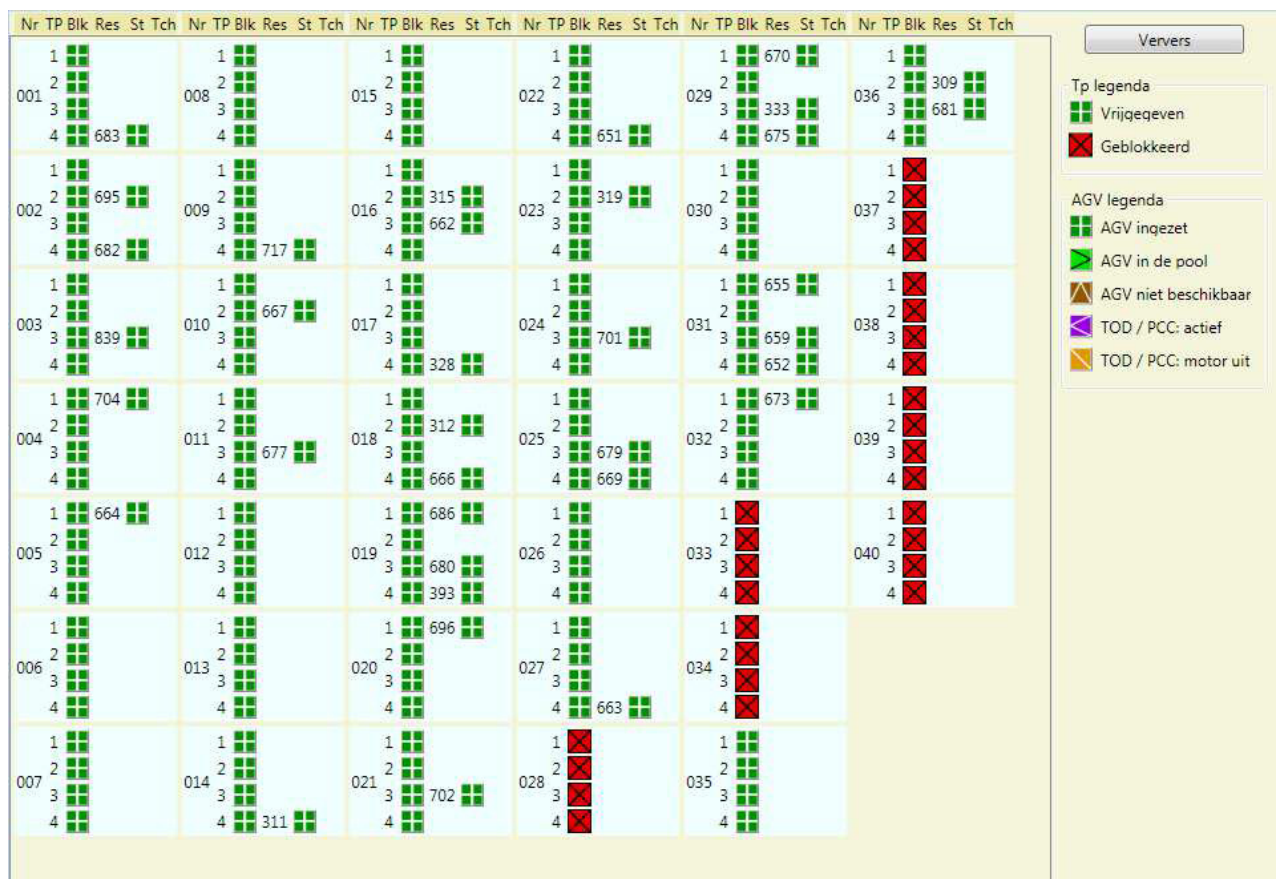
ASC Waterside Transfer Points overview screen

ASC sub stacks overviews
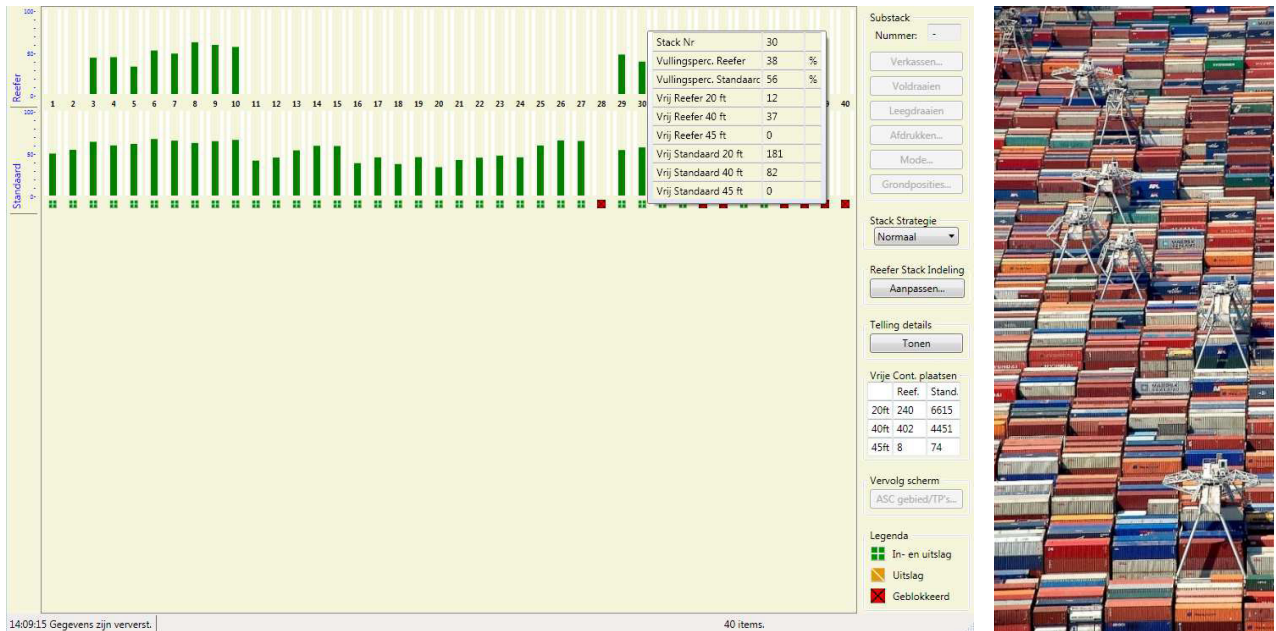
ASC sub stacks overview

ASC sub stack layout can be viewed and analyzed to monitor an important part of the terminal operation. PCS assigns incoming containers automatically to ASC sub stacks where there is room available. If PCS has received information from the TOS about future destinations or handling operations, PCS can take that into account. In practice, this information is not always available from TOS at the time containers have to be stacked. Operators can issue internal transfer operations in order to move containers or groups of containers from one sub stack to another. This can be useful when containers are expected to be retrieved from the stack and are to be loaded to a ship at a certain part of the quay.
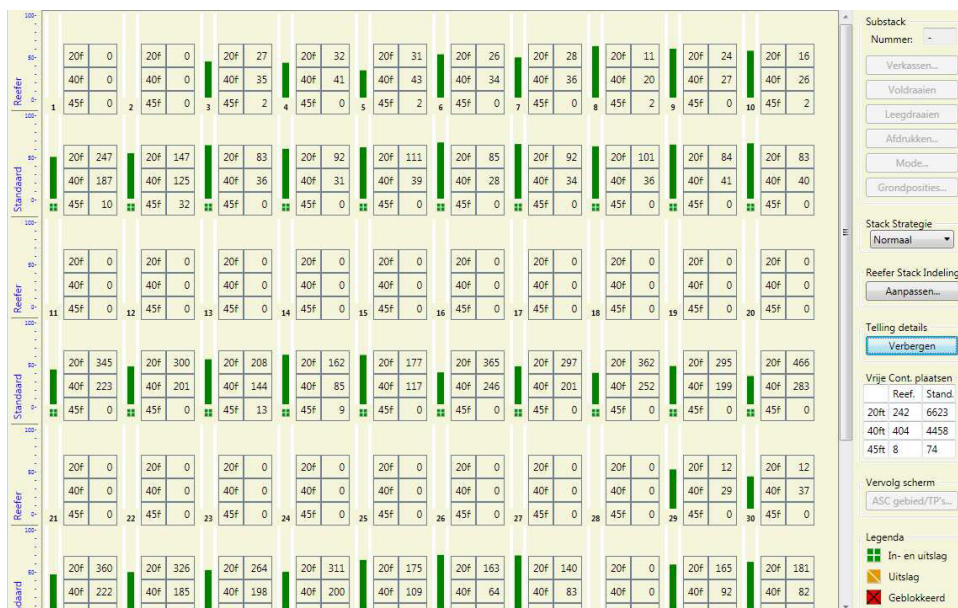
ASC Overview relative stack usage – free places

7 PCS Screen examples – equipment overviews

ASC Equipment overviews

ASC overview screens show the actual operational status of each of the ASCs. Operators can anticipate and react on exceptional situations, like defective ASCs, equipment which need maintenance etc.

Equipment, ASC status overview screen

Equipment, ASC status detail screen

AGV Equipment overviews

AGV overview screens show the actual operational status of each of the AGVs. Operators can anticipate and react on exceptional situations, like defective AGVs, equipment which need maintenance etc. Planning of refuelling of AGVs is important to keep the fleet of AGVs as much available as possible at all times.

AGV Overview

AGV Detail screen

QC Equipment overviews

QC overview screens show the actual operational status of each of the QCs. Operators can anticipate and react on exceptional situations, like defective QCs, equipment which need maintenance etc.

QC overview

The QC detail screen shows all QC related information: the AGV currently handled by the QC and which containers are transported.

QC Detail overview.

Manned equipment overviews

The manned equipment overview screens show the status of manned equipment such as SC's, TT's and Reefer Cars (RC's). From the overview screen, operators can select detail screens or a list of operational commands waiting to be executed.

Manned Equipment overview
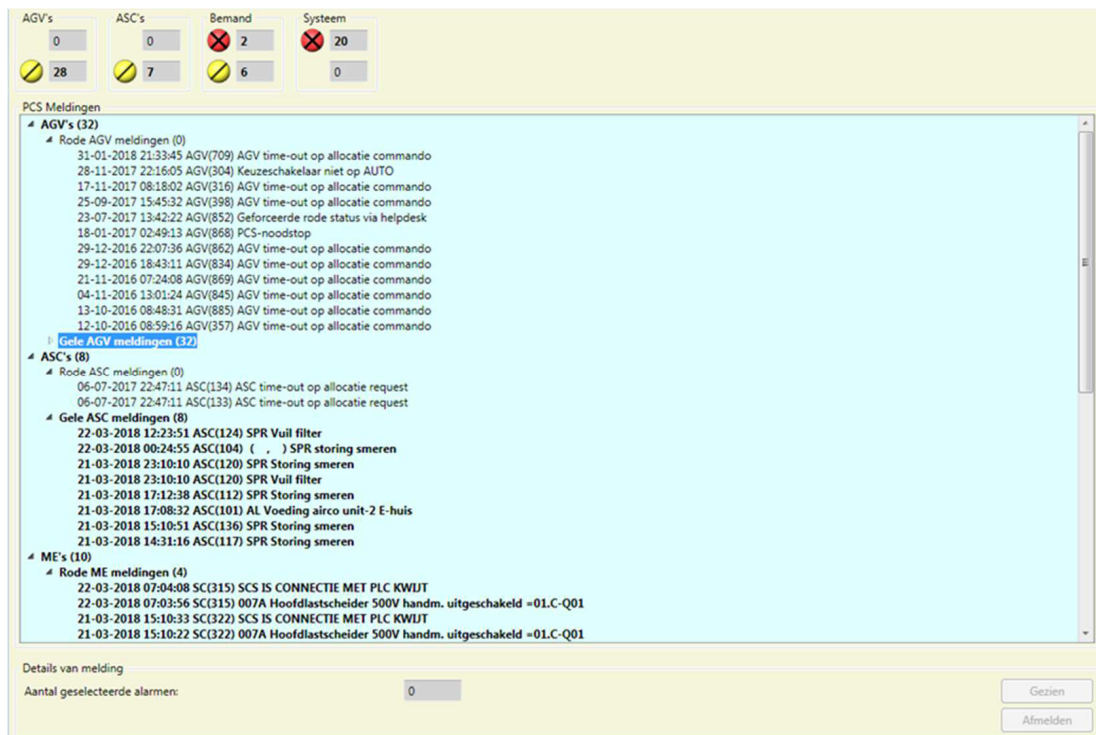

Manned Equipment detail screen

Manned Equipment orders waiting for execution

8 PCS Screen examples – other functions

Alarm Panel

Alarm Panel screen

Container info

PCS has extensive functions to display and alter container data for individual containers. Data per container can be displayed, edited and saved, as well as the locations of the particular container. Container data administration is however not a major task for PCS, while administration belongs merely to TOS.

Emergency stop system

At several points outside on the platform, stop buttons are installed to provide a stop function to personnel in case of emergencies. In many places this function is also installed on PCs. With this application, AGVs and/or ASCs can be stopped immediately. Depending on the area, only AGVs and ASCs in the direct neighbourhood of the stop button is stopped, or all ASCs and AGVs are stopped.

Operator / Helpdesk / Tester

For technical maintenance personnel, a number of supporting applications is available, e.g. to start and stop the PCS system, show error reports, make exports, tools for problem analysis. Tooling is provided to simulate the behaviour of equipment, generate messages etc. From registered data, operations can be replayed for analysis, testing, performance measurements and regression tests. On the other hand, simulation tooling is provided with which equipment can be tested, as if it were connected to PCS. In this way, new equipment can be tested prior to operational usage without having to disturb the operation.

Interested in Process Control System for your own Container Terminal? Please contact Bart Overgaauw of Transport and Logistics at the ICT Group:

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