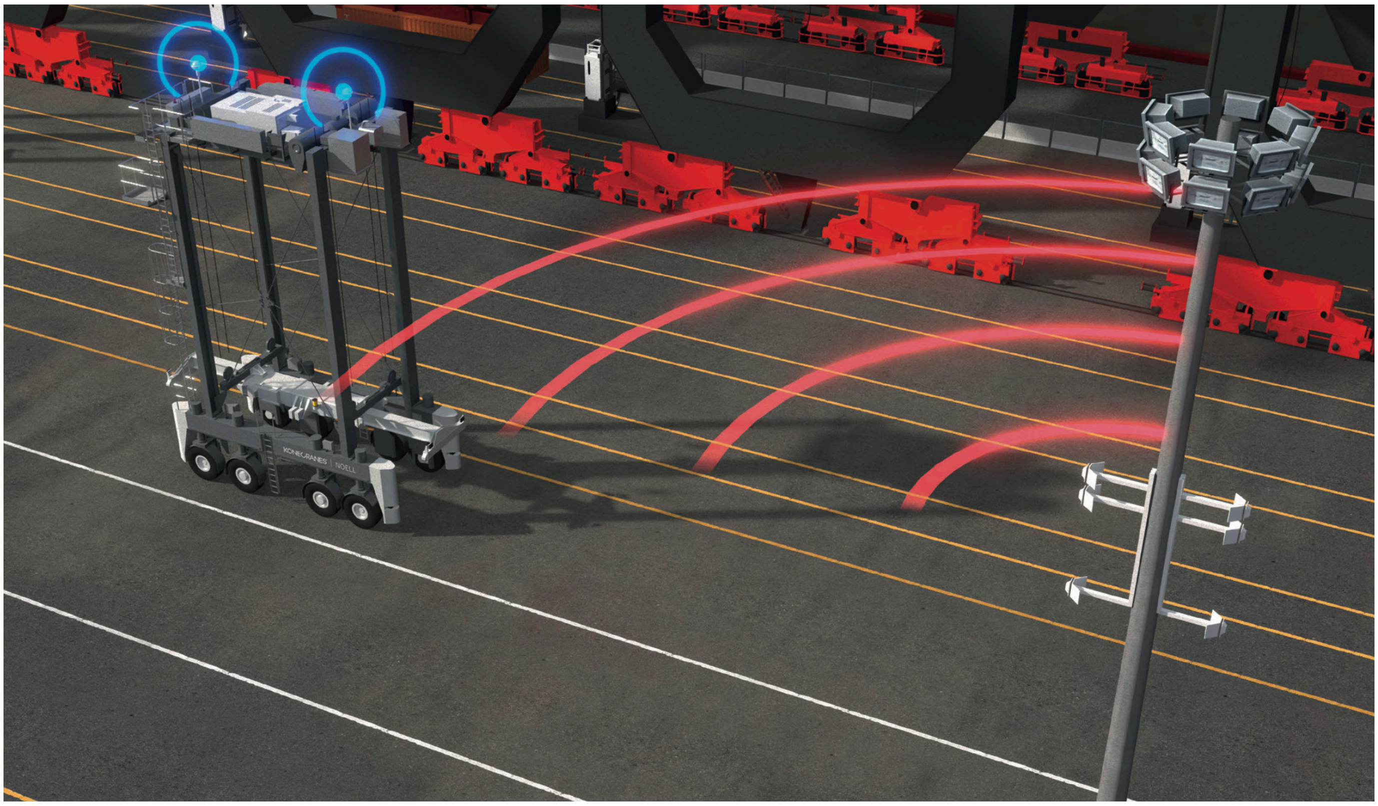
Automating Yard Operation in Brownfield Container Terminals: Crane Modification

A PEMA Information Paper



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This information paper provides an overview of issues to consider when automating a variety of container crane types, explores various challenges that need to be addressed, and offers insights into the extent to which automation of existing container equipment is possible and desirable.

This paper is the second part of a two-part PEMA Information Paper. The first part of this paper – Automating Yard Operation in Brownfield Container Terminals: Infrastructure was published in 2019.

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1. INTRODUCTION

DOCUMENT PURPOSE

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This information paper provides an overview of issues to consider when automating a variety of container crane types, explores various challenges that need to be addressed, and offers insights into the extent to which automation of existing container equipment is possible and desirable.

The paper illustrates the benefits of automation, such as continuous operations, personnel safety, operational efficiency and environmental impact. It also describes the systems and components used to automate cranes based on equipment type and infrastructure characteristics. It outlines potential strategies for implementing partially and fully automated yard operations to minimize disruption to day-to-day operations.

This paper is the second part of a two-part PEMA Information Paper. The first part of this paper – Automating Yard Operation in Brownfield Container Terminals: Infrastructure, was published in 2019.

This part of the paper focuses on the range of changes necessary to automate a variety of different crane types.

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2. EXECUTIVE SUMMARY

New-build container terminals have seen the benefits of automation in terms of increased safety, greater productivity, improved predictability, and reduced environmental impact. There is now growing interest in bringing varying degrees of automation to brownfield container terminals.

The key to successful brownfield automation is to limit disruption to operations. Furthermore, operations should be developed in such a way as to ensure personnel become familiar with new routines gradually. This helps ensure greater operational efficiency and reduces the risk of system failure or hazardous situations. Specific approaches will vary between terminals due to the differences in local conditions and the types and composition of equipment currently in use.

3. EQUIPMENT AUTOMATION MODULES/SOLUTIONS

3.1 MOVING THE LOAD

The load shall be moved in a safe, fast and accurate way, whether in manual or in automatic operation mode. In general, the following requirements are considered vital, depending on user needs and the degree of automation.

- Accurate stacking
- Pick- and drop automatically
- Safe load travel
- Driver Assistance
- Improved Crane performance
- Smooth handling of the container and goods in the container

The manual, semi-automatic and fully-automatic operated crane has to know the position of the load and the container and/or vehicle on the ground.

The goal is to bring two partners into the right position as quickly as possible without collision.

The interacting partners are:

1. The load on the crane, i.e. Spreader or Spreader with Container
2. The location of the Target
   a. Container in the yard
   b. Transport vehicle with or without container
   c. Container in the transfer area

LOAD POSITION

Load position means the position of the spreader with or without container.

The positon of the load can be measured by different measurement systems. The position can then be presented as a combination of measurement results from the different sensors systems.

For the load position the following information is necessary:

1. Gantry position
2. Trolley position
3. Hoist position
4. Headblock/Spreader position

Positions above can be measured by different measurement methods.

The second partner has to be measured from the crane.

TARGET POSITION

Target position means the location of the Container either in the Yard, in the Transfer Area and also the transport Vehicle.

Position measurement of container and vehicle using 2D- and 3D-Laser measurement systems is widely in use. Some application requirements can also be supported/solved by utilising camera systems.

The following chapters describe the different modules and solutions for the automation of the equipment.

3.2 EQUIPMENT POSITIONING SYSTEMS

3.2.1 RTG GANTRIES

3.2.1.1 DIESEL POWERED RTGS OR ELECTRIFIED RTGS WITH CABLE REELS:

To overcome the limitations of GNNS (Global Navigation Satellite System) positioning technology it is possible to use transponder technology to provide all-weather auto steering functionality and absolute gantry positioning. Each Gantry side should be fitted with an antennae and a row of transponders are installed along both sides of the stack.

3.2.1.2 ELECTRIC RTGs WITH CONDUCTOR BARS

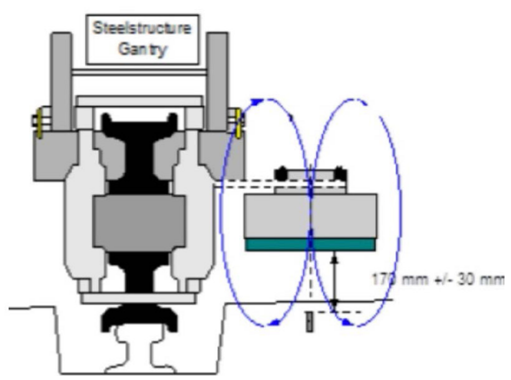
Most electric powered RTGs with conductor bars feature position measurement systems at the conductor bar side as part of the installation. To augment this system and to provide superior control of crane skew, it is possible to use transponder technology at the opposite side of the gantry structure from the conductor bar installation. In such cases, the gantry assembly should be fitted with an antenna and a row of transponders should be installed along that side of the stack.

Photo 1

3.2.2 RMGs (Rail Mounted Gantries)

The positioning of rail-mounted equipment tends to be generally performed using wheel mounted encoders. Because of wheel slip and wheel diameter changes (wear), encoders are typically re-calibrated at certain points along the stack. However, in between these re-calibration points, (because of slip or wheel wear), position inaccuracy may be significant and depend on direction of travel. This effect is amplified when two cranes work in one stack. The result is possible crane skew and results in unnecessary micro motions around the target position when the laser scanners detect a final target position deviation. In the event of a malfunction of the re-calibration point (physical obstruction, damage or weather influence) position accuracy will decrease and position deviation will increase. To overcome this problem and improve safety, it is an option to use transponder technology to provide all-weather, continuous absolute gantry positioning. The system acts like a linear encoder and works in conjunction with the pulse encoder located on a wheel or motor. Both gantry legs should be provided with a transponder antennae and a row of transponders must be installed along both sides of the stack. With such an arrangement 2mm position accuracy data will be provided to the crane PLC at all positions along the stack for “first time right” target finding.

It also provides for synchronisation of both crane legs. In the event of Power loss and at each power “on” the absolute position of the gantry is given directly at every position along the stack without the need to move to a calibration point.



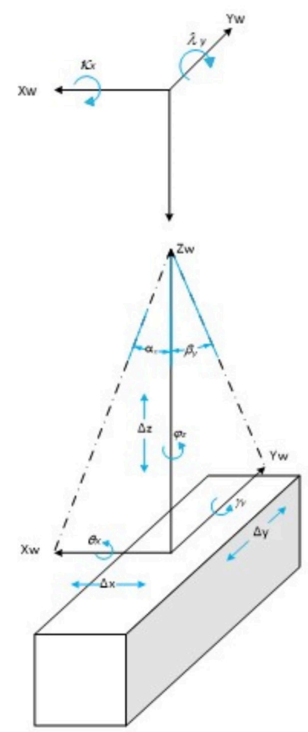
3.2.3 RTG/RMG/CRANE TROLLEYS

Positioning of crane trolleys tends to be performed by wheel encoders. Because of wheel slip and wheel diameter change (wear) typically the encoder has to be re-calibrated at certain points along the girder. However, in between these re-calibration points, (because of slip or wheel wear), position inaccuracy may be significant and will depend on direction of travel. This results in unnecessary micro motions as well as possible trolley skew, depending on the design, around the target position when the laser scanners take over to detect a final target position deviation. It is possible to overcome this problem by using a linear encoder, laser / radar distance sensors or transponder technology. Transponder technology is able to “absorb” significant deviations resulting from inaccurate installation or motion/sway in the crane structure as it does not require direct line of sight to fixed reference points on the crane. Transponder technology provides all-weather, continuous absolute position data. The system acts like a linear encoder and in combination with ta pulse encoder on a wheel or motor. At least one side of the trolley should be provided with a transponder antenna and a row of transponders must be installed on the same side of the girder. The result is that 2 mm accurate position data will be provided to the crane PLC at all positions along the girder for “first time right” target finding. After power “off/on” the absolute position of the trolley is available directly at every position along the girder without the need to move to a calibration point.

3.2.4 SPREADER POSITIONING/ LOAD MEASUREMENT

Because of wind, rope stretch or unevenly loaded containers, the position of a spreader/ headblock tends not to be exactly vertically or horizontally aligned underneath the intended centreline of the hoist trolley. To control sway and to make auto stacking possible, the position of the spreader relative to the hoist trolley must be known. Specific infrared (IR) measurement systems are available on the market to detect the offset, skew, distance and trim/list of the spreader relative to the hoist trolley.

The most robust systems – capable of withstanding harsh environments such as UV light and large measurement distances work with an active IR beacon on the spreader assembly with an IR receiver on the trolley. The latest versions also provide deflection data of the trolley to compensate possible deflections of the crane structure (i.e. RTG on tyres, uneven rails or heavy loads on the crane). When the gantry and trolley positions, and the relative position of the spreader to the trolley is known, and sway is under control, the spreader can be lowered to its target position. Because the number of sensors on cranes have increased significantly and as specialised knowledge is not always available at container terminals, particular attention must be given during design to reducing the number of sensors wherever possible. Selection of systems that are easy to install and that require as little maintenance as possible should be considered.



Symbol	Axis (world)	Measurement	Type	Unit
Δ_x	X	Offset X	Translation	[m]
α_x	X	Sway X	Rotation	[°]
$v_{\Delta x}$	X	Sway Speed X	Velocity	[m/s]
θ_x	X	Trim	Rotation	[°]
κ_x	X	Autolevel X	Rotation	[°]
Δ_y	Y	Offset Y	Translation	[m]
β_y	Y	Sway Y	Rotation	[°]
$v_{\Delta y}$	Y	Sway Speed Y	Velocity	[m/s]
γ_y	Y	List	Rotation	[°]
λy	Y	Autolevel Y	Rotation	[°]
Δ_z	Z	Distance	Translation	[m]
$v_{\Delta z}$	X	Hoist Speed Z	Velocity	[m/s]
ϕ_z	Z	Skew	Rotation	[°]
$v_{\phi z}$	Z	Skew Speed	Angular Velocity	[°/s]

Figure 1: Possible Deviations of Spreader/Container relative to the crane

3.3 TARGET POSITIONING SYSTEMS

3.3.1 TECHNOLOGIES

3.3.1.1 2D- AND 3D-LASER MEASUREMENT SYSTEMS

With a combination of several 2D-Laser scanners or with 2 x 3D-Laser scanners mounted on cranes, the positions of containers in yards can be measured.

The use of such laser technology installed on the underside of the trolley allows measurements over long distances, from tier 1 to Tier n, to detect the position of containers.

3.3.1.2 CAMERA SYSTEMS ON SPREADERS

Four camera systems are installed on the sides/ corners of the spreader. The images of the container corners are used to determine the exact position of container corner castings.

Camera systems are used for near-field applications i.e. close to final pick or drop positions.

3.3.2 FUNCTIONS

The following functionality (f) is required to support either manual, remote operation or fully-automated cranes.

3.3.2.1 AUTOMATIC YARD OPERATION

In the yard a container has to be picked up or has to be dropped onto another container or ground slot. This can be performed using laser or camera-based measurement systems, which are the in effect the eyes or the crane.

The following is a description of a 2x 3D laser scanner-based system which is installed underneath the trolley.

The 2x 3D laser scanner measure over the two long sides and the four container corners to determine the position of the container that has to be picked up or being deposited in position.

The sensors also measure the gap around the container in the slot to ensure that the spreader can be lowered without colliding with the adjacent container stacks.

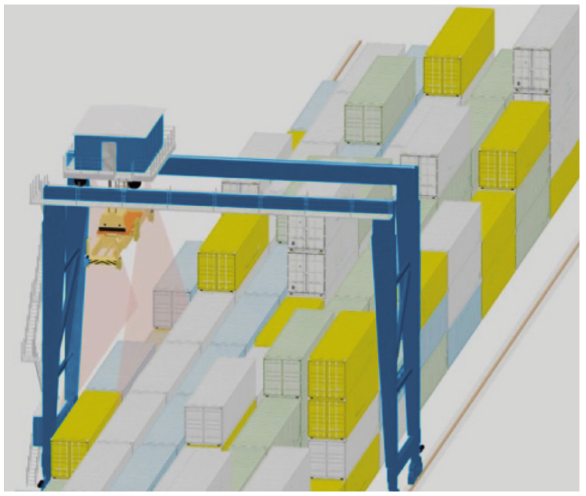
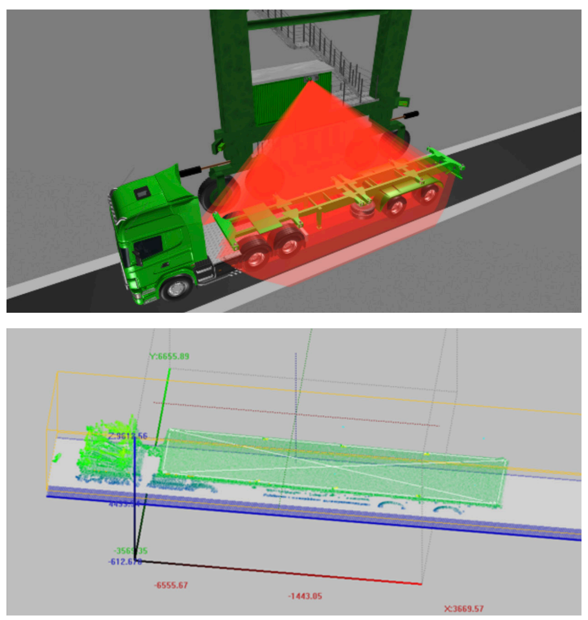


Image 1: 2x 3D laser scanner underneath the trolley. The two 2D-scan planes are shown in red. Both 2D-scan planes will be swivelled across the container sides.

3.3.2.2 UTOMATIC PRIME MOVER, ROAD TRUCKS, AGV HANDLING

When vehicles such as prime mover, road trucks or AGVs are the partners on the ground for container exchange, then the outer dimensions, significant structural characteristics and/or the twistlocks (road trucks) can be the indicators for the position of the transport vehicle. Laser technology is typically used for applications of this type.



Images 2&3

A 2D- or 3D-laser scanner measures the position of the truck relative to the centre of the crane. When the load is coming from the stack, the trucks are already in the right position in the gantry axis. A 3D-laser scanner can also measure the position of the trailer (chassis) in trolley axis as well as the rotation of the trailer around the height axis.

In the case of a road trailer the twistlocks can also be measured to allow for an automatic truck handling process.

When using AGV's the position of the AGV and/ or the position of the container on the AGV has to be measured.

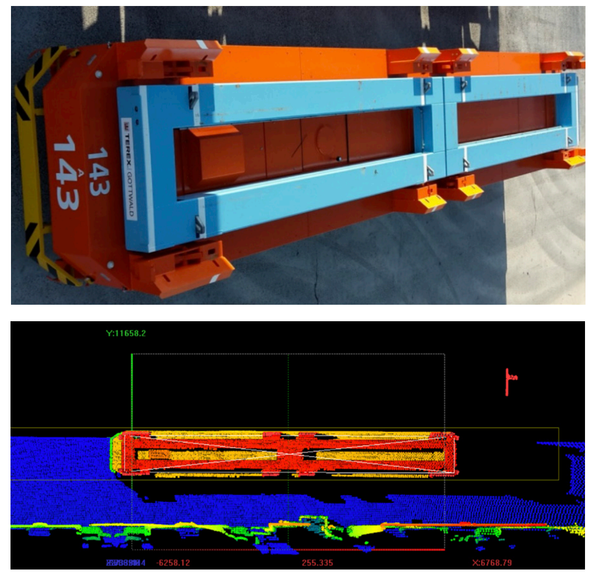


Photo 2: AGV and the 3D laser Point cloud. | Image 4

3.3.2.3 TRUCK POSITIONING

To optimise crane performance, trucks should be positioned at the centre of the crane to allow container handover without repositioning of the crane or the ground equipment. A digital display signals to truck drivers their relative position to the centre line of the crane.

In the case of fully automated container handling, truck/trailer position has also to be measured in the trolley axis as well as the rotation of the vehicle/ container around the vertical axis.

Image 5: A scan plane "cuts" the container determining the front, rear and centre of the container. The truck driver receives feedback about his position in relation to the centre of the crane via a digital display.

3.3.2.4 AUTOMATIC STRADDLE CARRIER HANDLING

SCs pick and drop containers in the transfer areas. Here the same technologies will be used as in the stacking area.

3.3.2.5 STACK PROFILING

Stack profiling is used for:

1. Automated moves using optimal curves
2. Providing the basis for collision prevention
3. Soft landing

Here also 2D- and 3D-Laser scanner measurement systems are utilised. There are different systems available in the market. The simple systems measure only in the operation bay, the advanced systems also measure the container positions in the adjacent bays and the most advanced systems also measure the profile in the gantry direction.

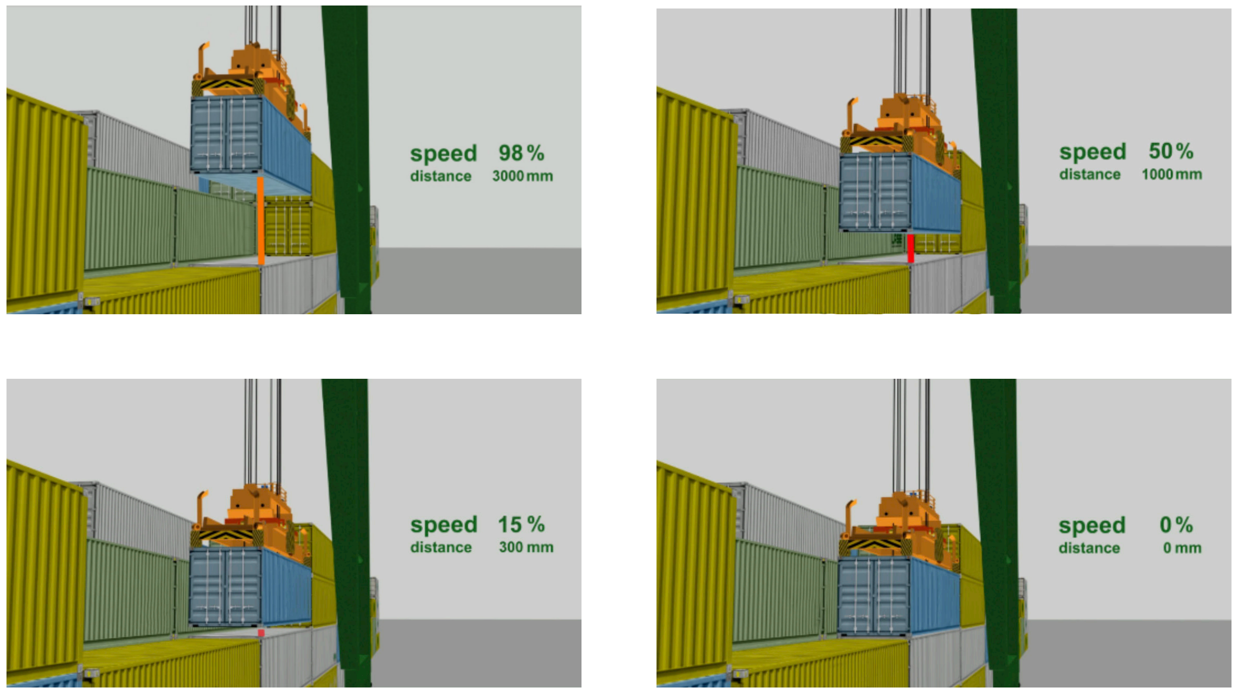
3.3.2.6 OPTIMAL CURVE

By knowing the height of containers and creating a complete 3D-image of the yard, loads can be driven in an optimal curve over the yard, without the need to hoist the load up into the highest hoist position whilst already in motion.

This is simpler for RTGs because the delivery to/from the yard is mostly coming from the truck lane side. Here just the operational bay and the adjacent bay (advanced system) have to be observed. With RMGs every row has to be measured and visible well in advance such that the load height can be adapted to the height of stacked containers.

3.3.2.7 SOFT-LANDING

Soft-landing technologies are designed to prevent containers being dropped with unnecessarily high impact. In this scenario the crane driver in the cabin and the ROS crane driver have some additional sensor support by way of measurement systems Such sensors measure the distance either from spreader to the container below or from lifted container to the ground or vehicle and slows the hoist motion. Thus, the container (spreader) will be dropped gradually. This avoids high spreader repair and maintenance costs and damage to goods inside containers.



Images 6-9: Distance and load speeds at different landing stages.

3.3.3 SAFETY FUNCTIONS

3.3.3.1 COLLISION PREVENTION

Collision prevention solutions differ between RTGs and RMGs as well as to the degree of automation applied. Operators also need to decide what sort of collision is to be prevented, i.e. collisions in:

1. Operation Bays
2. Adjacent Bays
3. Direction of Gantry Travel

For cranes operated by a driver in the crane cabin or by a ROS, the measurement system must support the driver. It should help him or her to avoid hitting containers when moving around the yard, (a so-called driver assistance system).

In the case of fully automated cranes, yard management systems usually “know” the yards where they are operational and know how all stacks have been filled. However, containers can be shifted by wind or placed wrongly during manual interventions.

Measurement systems compare the actual position of the load with the height profile of containers in the yard. They also calculate stopping distances on the basis of actual data on speed, drive and brake behaviour, latency times and load swinging behaviour.

COLLISION PREVENTION IN OPERATION BAYS

Image 10: With 2 x 2D-laser scanner bays can be scanned. Additionally, laser scanners measure reference marks on the headblock. By comparing the position of both objects containers in yard and the load position a collision in the bay can be prevented.

COLLISION PREVENTION IN ADJACENT BAYS

By using 1 x 3D-laser scanner and 1 x 2D-Laser scanner, adjacent bays can be scanned. 25% of accidents where containers are knocked down occur with containers in adjacent bays. These incidents tend to be more severe when containers are knocked over in the first two rows of a yard due to trucks, cabins being in the adjacent bay.

Image 11

COLLISION PREVENTION IN EQUIPMENT INTERFACE ZONES

APPLICABLE TECHNOLOGY

3.3.3.2 TRUCK LIFTING PREVENTION

When containers are lifted by spreaders from trucks, failure to release twistlocks properly, or in the case of gooseneck trailer when the container jams in the structure, can result in the trailer being lifted from the ground. In both cases a measurement system is required to monitor whether the trailer/truck is being lifted with the container.

In such a case a 2D-Laser scanner can be used with a vertical scan plane that measures the position of the trailer structure and the container. When both objects move upwards simultaneously, this is an indicator of a lifted truck/trailer scenario.

Image 12: Scan plane in red. Motion has been stopped by the indicator that trailer is going upwards together with the container.

3.4 TRUCK AND CONTAINER IDENTIFICATION

Gate traffic has increased markedly in recent years. Many advanced terminals use various kinds of technology to support gate operations such as verification, confirmation and registration of driver, truck, chassis and container data.

All of the 17 million containers in the world have a unique code standardized by ISO 6346 [1]. Automatic container code recognition systems have been developed for automated transportation and the monitoring of container flows. The two most popular solutions are radio frequency identification (RFID) and optical character recognition (OCR). Each of these solutions have their own relative strengths and weaknesses. RFID-based solutions tend to offer a high degree of accuracy but have higher installation and maintenance costs than alternative solutions. OCR-based solutions are typically less accurate but do not require containers to be tagged. Use of a vision based system can provide automatic identification of container numbers, seal integrity, door handle state and lock and door orientation.

3.5 AUTOMATION SYSTEM DIAGNOSTICS

For all automation solutions, it is essential to diagnose faults quickly. In the case of system or hardware faults, this is possible on the basis of error message systems generated by the components used. However, if a process error shows an incorrect value from a measurement device, such an analysis is only possible if the corresponding information for the individual process steps is already available. With accurate diagnostics it is possible to implement functions which mitigate against safety critical fault modes and signal deviations.

For automation solutions in container terminals, rapid diagnosis of faults is crucial to avoid a costly disruption in operations. In the automation process this can occur as a result of an accident or unwanted event. In such a case it is important to understand the cause as quickly as possible and at a later time to work out appropriate corrective measures.

Another criterion is the continuous optimization of the automation process. To achieve this, appropriate detailed data is needed which can be achieved by the implementation of process logging. It is important that all intelligent components involved in the automation process log their individual process steps and make this information centrally available in a time-synchronized manner.

3.5.1 WHAT IS DIAGNOSED

As on-board diagnostics is mainly integrated in electronic control systems, we consider this issue from that point of view.

The electronic control system consists of sensors, controllers, actuators and communication links. The controllers are normally programmable. The electronic control system controls the mechanical system including hydraulic, pneumatic and electro-mechanical sub-systems to make the machine implement the desired task. There are three identified diagnostic levels:

1. Diagnosis of the control system (sensors, connectors, cables, CPU, RAM, I/O electronics, actuators and communication sub-systems)
2. Diagnosis of the mechanical system (fluid quality, fluid levels, fluid pressure, temperatures, bearing wear, load, etc.)
3. Monitoring of the efficiency of the process and the quality of the output produced (successful container picks, path tracking accuracy of the machine)

The **seven-layer** architecture (OSA-CBM) can be used to segregate the diagnostics sub-systems into modular and well interfaced entities.

1. Data acquisition (sensor module which output calibrated sensor signal values)
2. Data manipulation (signal processing; e.g. mean value calculation or frequency spectra)
3. Condition monitoring (e.g. range checking, alerts)
4. Health assessment (diagnostic processing; e.g. fault condition evaluation)
5. Prognostics (e.g. estimation of remaining useful life)
6. Decision support (e.g. 'limp home' instructions and automatic reconfiguration)
7. Presentation (user interface)

Considering on-board diagnostics on an automated working machine, the simplest diagnostics activity to implement is the data acquisition layer to provide data for remote off-board diagnostics such as the cloud environment. If the amount of data to be transferred is large, it may be better to include the data manipulation layer to provide only some characteristic parameters of the measured signals. The more sophisticated on-board diagnostics and problem solving required, the more layers that have to be implemented.

4. CONSIDERATION FOR SAFE OPERATION

4.1 EQUIPMENT OPERATION

In green-field automated terminals, the lay-out of the operation and associated safety concepts is already planned from the start for automation. The lay-out of such terminal typically provides for total separation of the automated machines from the human-driven machines by e.g. fencing (e.g. ASC-terminals with dedicated land-side and water-side transfer zones). In the case of brown-field automation however, the existing operation of the terminal is often based on the free co-existence between transport vehicles (e.g. street trucks and terminal tractors) and stacking cranes like RTG's and straddle carriers. The mutual proximity of these vehicles has generally not been a problem as human operators were ultimately responsible for safety on all machines. However when the operators are removed, the automated (driverless) vehicle need to be inherently safe. For example, collisions with different types of vehicles as well as with the possible presence of pedestrians shall be avoided with high reliability.

4.2 MAN MACHINE OPERATION (MAN MACHINE CO-EXISTENCE IN AN AUTOMATED TERMINAL)

Photo 3

MIXED TRAFFIC LAY-OUTS

By a "mixed-traffic" lay-out is meant a lay-out where driverless vehicles drive close to an operator-driven vehicle without a separating fence between them or in a shared area. Theoretically, it is possible that the vehicle operator may leave the vehicle cabin unless prevented or monitored by special means. Typical such mixed-traffic lay-outs of container ports could be e.g.:

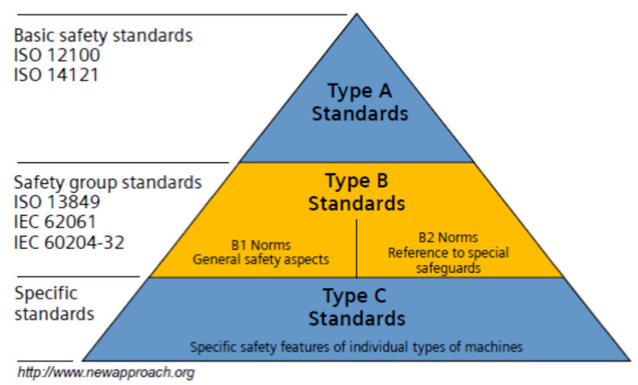
- RTG terminals where the street trucks drive along truck lanes under driverless RTG:s.
- Straddle carrier terminals where driverless straddle carriers load and unload street trucks
- Straddle carrier terminals where driverless straddle carriers and operator-driven straddle carriers handle the same containers

In order to maintain safety in such an environment, a reliable navigation and position reporting system is also essential for the manned vehicles. Real-time location information of the mixed fleet enables safe path planning of the AGV's.

4.3 PROVING THE SAFETY OF OPERATION

The equipment manufacturers are required to prove that their equipment is safe. Especially in EU-countries port vehicles must fulfil the so called Machine Directive requirements. If the vehicle is driverless, the overall safety clearly cannot be left to the responsibility of the driver of co-operating equipment or other attendant port personnel. The proof of safety requires a special Risk Assessment Procedure (reference 5.) for each specific application (for each crane, port and operation type). It is often very time consuming to make such a risk assessment, and standards are typically generated in order to simplify this task. A "c-type" standard applies which inherently should include such a risk assessment which has already been prepared for a specific application whereby it is sufficient for the equipment manufacturer to follow the instructions of the standard. Such safety standards exist for example for indoor factory-AGV's (e.g. ISO 3691-4) and for Cranes – Bridge and Gantry Cranes (EN 15011).

LEVEL OF STANDARDS A, B, & C



Chinese equivalent
ISO12100: GB1570
IEC 60204-32: GB5

Figure 2

STATUS OF STANDARDS FOR CONTAINER PORT APPLICATIONS

Many outdoor heavy work machines have their own dedicated standardization groups, e.g.:

- TC127 Earth-moving machinery
- TC82 Mining
- TC23 Tractors and machinery for agriculture and forestry
- TC22 Road vehicles

However, port vehicles do not have their own dedicated group. Some smaller port vehicles are formally in the scope of "TC110 Industrial trucks", but this standard is mainly focused on indoor factory-AGV's. The biggest shortcoming of this standard is that the technical solutions presented therein are only feasible for an indoor environment and short detection distances. For example, SIL2 -safety level rated laser scanners are not presently available for longer distances in less-than-optimal outdoor weather conditions. This is a specific requirement because of the higher speeds of some port vehicles. The safety-approach presented in, for example, the earth-moving, agricultural and mining industries could in fact be considered as more suitable for port environments.

Photo 4

AVAILABLE SAFETY SENSOR TECHNOLOGY FOR OUTDOOR OPERATION

The environmental conditions for outdoor operation are challenging when compared to indoor operations. The illumination levels could be as high as 100.000 lux in direct sunlight and, on the other hand, the visibility could go down to 10 meters MOR (Meteorological Optical Range) near the sea. It is especially difficult to detect dark objects (e.g. 2% reflectivity) through heavy fog. Other ambient conditions where manned vehicles still continue to operate typically include rain (e.g. 10 mm/h) or snowfall (e.g. 5 mm/h SWE, Snow Water Equivalent).

Only now have the first safety-certified sensors (typically laser scanners) for outdoor conditions arrived on the market. The safety integrity of the system is not based on the sensor operation alone, but on the safe integration between the sensors and the control system of the AGV's (IEC 62998, reference 6).

In the case of bad weather conditions, the sensor needs to be able to diagnose the situation correctly and report this to the control system of the AGV. The safety rated AGV logic and hardware needs to take the necessary action in order to maintain a safety condition (e.g. reduce speed or stop operation). In practise this means reduced availability (e.g. downtime) of the machine at the port terminal.

Photo 5

4.4 REQUIREMENTS FOR SAFETY

Where risks to people and life resulting from the risk assessment based on the Machinery Directive are identified, measures must be taken to reduce such risks. These are the requirements for the safety of the operation. General safety requirements have been defined in different standards based on either a SIL- or PL- rating [reference1, reference2]. Standard IEC 620061 refers to SIL classification and generally refers to Electrical safety aspects whereas Standard EN-ISO 13849 refers to PL classification. For example, if a safety-critical failure can cause the death of a person, a typical safety requirement according to EN-ISO 13849 is "PLd". If however the person has a good chance to escape the dangerous situation, the requirement can be reduced to "PLc" (Fig. 3, reference 3).

Depending on the required safety level, a certain maximum probability of dangerous failures of equipment and sensors is defined. There is a correlation between the standards and as an example, a safety requirement of "PLd" typically requires a laser scanner of "SIL2" classification to IEC 62061 to detect possible pedestrians on the travel path. A sensor with such reliability has a failure to danger probability of less than one in a million in one hour (Fig. 4, reference 4.)

Safety Integrity Level	Probability of Dangerous Failure per hour
SIL 4	>= 10^{-9} to 10^{-8}
SIL 3	>= 10^{-8} to 10^{-7}
SIL 2	>= 10^{-7} to 10^{-6}
SIL 1	>= 10^{-6} to 10^{-5}

Figure 4

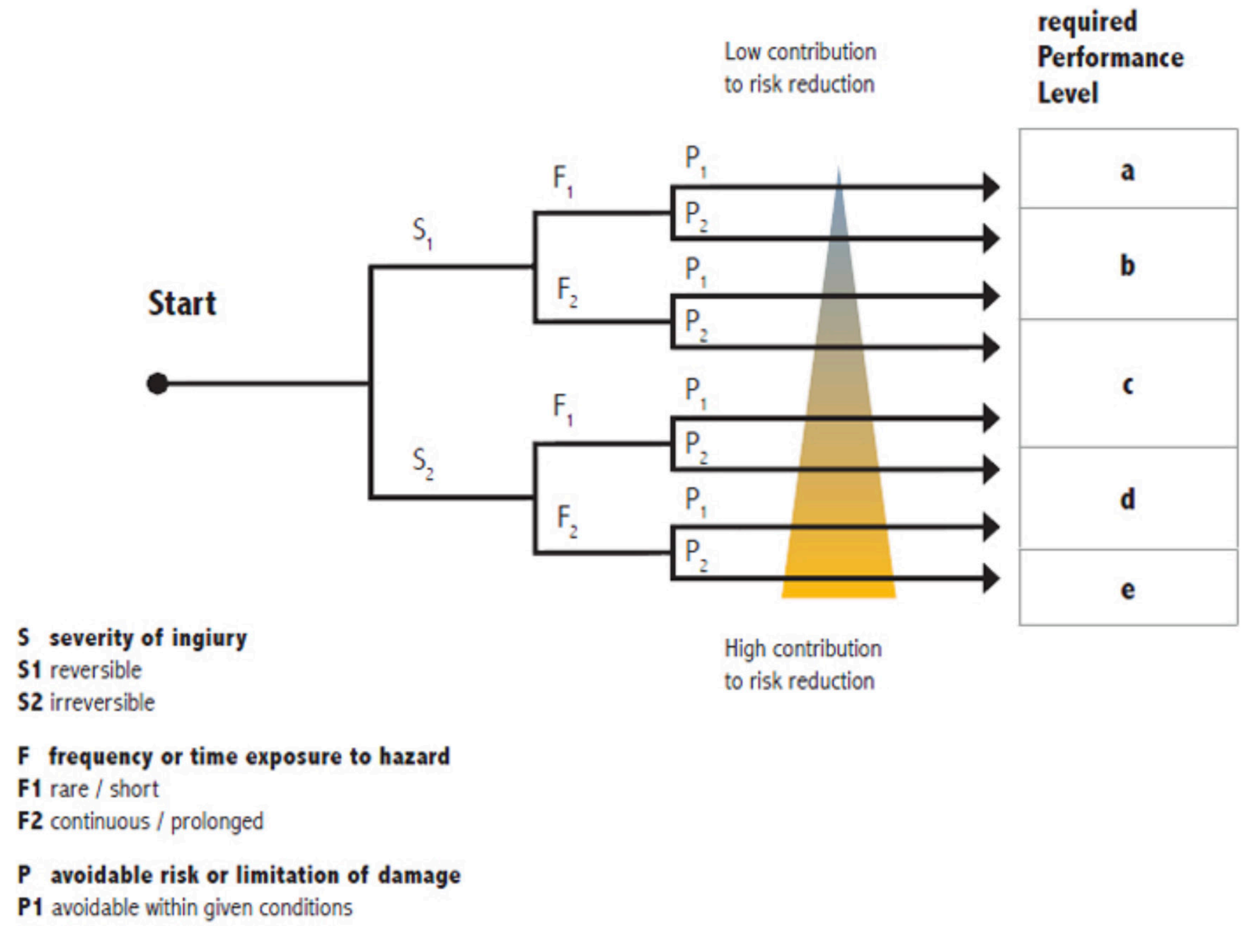


Figure 3

FAILURE TO DANGER AND AVAILABILITY

"Failure to danger" is a situation where e.g. a sensor fails to see a true hazard situation, e.g. a person standing in the travel path of an AGV. The opposite situation, where a sensor causes a "false alarm" (because of e.g. rain drops or fog) does not compromise safety, but instead, reduces the usability of such sensor. It is often challenging to optimise the sensitivity level of such sensors such that the safety requirement is fulfilled while minimising the number of false alarms which are generated. This challenge is especially demanding in an outdoor environment. The prevailing weather conditions (e.g. rain or fog) may cause periods of "unavailability" of an AGV, should the sensors not be able to guarantee the safety of operation when driving.

5. REFERNECES

"The Yard Revolution, Automated RTG", Konecranes

"Plan Your Way to RTG Automation", Kalmar

"Converting a Manual RTG Terminal to an AutoRTG Terminal", Timo Alho, Tommi Pettersson, Mika Virtanen, Kalmar

"A-STRAD: for Brown, Green and Future Fields", Konecranes

"Conversion to Automated Straddle Carrier Terminal", Timo Alho, Michael Hickson

ABOUT THE AUTHORS

This paper was prepared by Alois Recktenwald, Siemens, and Kari Rintanen, Konecranes, with contributions from Kalmar, Kuenz and other PEMA members.

ABOUT PEMA

Founded in late 2004, PEMA's mission is to provide a forum and public voice for the global port equipment and technology sectors, reflecting their critical role in enabling safe, secure, sustainable and productive ports, and thereby supporting world maritime trade.

Chief among the aims of the Association is to provide a forum for the exchange of views on trends in the design, manufacture and operation of port equipment and technology worldwide.

PEMA also aims to promote and support the global role of the equipment and technology industries, by raising awareness with media, customers and other stakeholders; forging relations with other port industry associations and bodies; and contributing to best practice initiatives.

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PEMA membership is open to:

- Manufacturers/suppliers of port equipment
- Manufacturers/suppliers of port equipment components
- Suppliers of technology that interfaces with or controls the operation of port equipment
- Consultants in port and equipment design, specification and operations

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