Kalmar

AutoStrad™

terminal design and conversion

A Kalmar white paper
2023 Edition

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1 Introduction

Increasing the automation level of a terminal with products that automate a single part of the operation or the whole process is recognised as the next step towards improving performance at today's container terminals. The benefits of automation include lower operational costs as well as improved terminal productivity, capacity, safety and security.

Automating an existing terminal is a complex project that requires deep expertise, careful planning, a capacity for wide-ranging system integration and the ability to consider numerous factors beyond technical implementation. In addition to the actual automated system, there is also extensive change management required within the entire organisation of the terminal, as operating an automated terminal requires a thorough change of business processes and job descriptions, as well as different skill sets for the people operating the terminal.

...improving performance at today's container terminals.

In this paper, we examine a number of these areas, ranging from the financial impact of switching to an automated straddle carrier concept, to terminal and infrastructure design as well as technology options. Finally, we will look at total cost of ownership calculations for automated straddle carriers in comparison to other terminal concepts, as well as change management considerations.

2 The Kalmar AutoStrad™ system: Why automated straddle carriers?

The main reasons to choose a straddle carrier setup when compared to other terminal concepts include operational flexibility and simplicity.

THE SINGLE MACHINE APPROACH

Automated straddle carriers are suitable for the same types of terminals as manual straddle carriers. The main reasons to choose a straddle carrier setup when compared to other terminal concepts include operational flexibility and simplicity. In a straddle carrier terminal, a single machine handles the end-to-end container flow from stacking and horizontal transportation to the loading and unloading of landside vehicles. Other horizontal transportation concepts, such as those built around automated guided vehicles (AGVs), will always need another machine to stack the containers and handle landside operations.

A significant benefit of straddle carriers is that they enable fully decoupled operations, in which containers can be deposited on the ground without the need to have a specific machine always available to receive the container from the quay crane or stack. A straddle carrier terminal can also adapt easily to changes in terminal throughput. Excess machines are automatically parked away when not needed, and more equipment can be added as demand based on business priorities dictates. Each straddle carrier can be freely assigned to the landside or waterside operation, depending on where the handling capacity is needed. Additionally, in general, any straddle carrier can reach any container in the terminal, which provides huge flexibility. Furthermore, running only a single type of machine also simplifies maintenance and spare parts availability.

When considering the choice of automation solution and terminal concept, it is important to remember that the question is not an either/or choice. Hybrid terminal layouts utilising multiple horizontal transportation and/or crane technologies are also possible.

For example, if there is a need to increase the TEU capacity of an automated straddle carrier terminal in the future, one or more Automated Stacking Crane (ASC) blocks may be added to increase the stacking density. By starting with a straddle carrier solution first, the terminal can decrease its capital expenditure and time-to-operation at the beginning of the project, while retaining the option of adding ASC blocks if the long term capacity needs to be increased in the future. This incremental approach offers significant benefits in terms of costs, project scheduling and overall business risk management.

BENEFITS OF AUTOMATED OPERATION

An automated straddle carrier terminal offers several clear advantages over a traditional manual straddle carrier terminal. The most immediate and most easily quantified gain is significant savings in terminal operating expenses such as labour and maintenance costs. Other direct benefits include increased efficiency and flexibility, more predictable operations, higher availability, significantly improved occupational safety, better site security and longer equipment life spans.

An often-heard remark from people seeing an automated terminal for the first time is how smooth the operation seems. No aggressive driving is seen, no containers are banging on the ground, and everything proceeds in a steady, systematic fashion. In an automated terminal, horizontal transportation and lifting equipment is always utilised optimally. Collisions due to human error and unplanned repair tasks are eliminated.

Automated straddle carriers are able to operate as a single equipment pool, ensuring that machine utilisation rates are always maximised and unladen travelling minimised.

By contrast with traditional manually operated straddle carriers, automated straddle carriers are able to operate as a single equipment pool, ensuring that machine utilisation rates are always maximised, and unladen travelling minimised. Automated equipment also conserves resources and contributes to the sustainability of resources. Significant fuel savings are realised through optimal routing patterns with minimal empty driving, a reduced need for cabin air-conditioning or heating, and consistent implementation of engine stop functionality during equipment idle time. An automated terminal also requires less lighting in the yard, which decreases power consumption and reduces the environmental impact of operations.

AUTOMATED TRUCK HANDLING

One of the most significant developments for automated straddle carriers in the last few years has been the adoption of automated truck handling.

The loading and unloading of containers on road trucks has traditionally been the most difficult step in operations to automate, requiring manual intervention even in terminals that are otherwise fully automated. Automated truck handling for Kalmar AutoStrad™ is the first solution to enable the full end-to-end

Automated truck handling improves the safety, predictability and cost-efficiency of terminal operations by eliminating the need for personnel in the truck interchange zones.

automation of container handling at straddle carrier terminals. This feature has earlier been available for Kalmar yard cranes and has recently been added to Kalmar's horizontal transportation offering.

Automated truck handling automates the placement of containers from automated straddle carriers onto trucks in the terminal's truck interchange zones. The system measures the truck's profile, location and the container positions available, while an on-board camera imaging system on the Kalmar AutoStrad™ is used for precise positioning when placing the container onto the truck. Automated truck handling improves the safety, predictability and cost-efficiency of terminal operations by eliminating the need for personnel to be present in the truck interchange zones.

Automated truck handling is already in use at numerous automated straddle carrier terminals around the world, including at one of the world's largest mega terminals that runs the Kalmar AutoStrad concept, handling thousands of truck moves every day. Automated truck handling at AutoStrad terminals enables a fully automated container flow between quay cranes and trucks by automating the final stage of landside operations, all with one type of container handling equipment.

AUTOMATION SYSTEM: KALMAR ONE

The scope and type of automation required at an AutoStrad terminal – in which a fleet of up to several hundred machines handles all horizontal transportation and stacking tasks as well as truck lane operations – differs significantly from, for example, traditional ASC terminals with manual horizontal transportation. Kalmar One is a flexible and scalable open automation system for handling containers in ports and terminals. It enables terminals to streamline and automate their operations with proven functionalities and well-established processes. As a standardised open automation system, it is applicable for a wide array of container handling equipment types.

An automated straddle carrier terminal is a highly complex environment that requires coordinated control and decision making at the level of the entire terminal. Kalmar's approach to terminal automation is based on centralised routing and scheduling that utilises information and data received via open Kalmar Key automation interfaces.

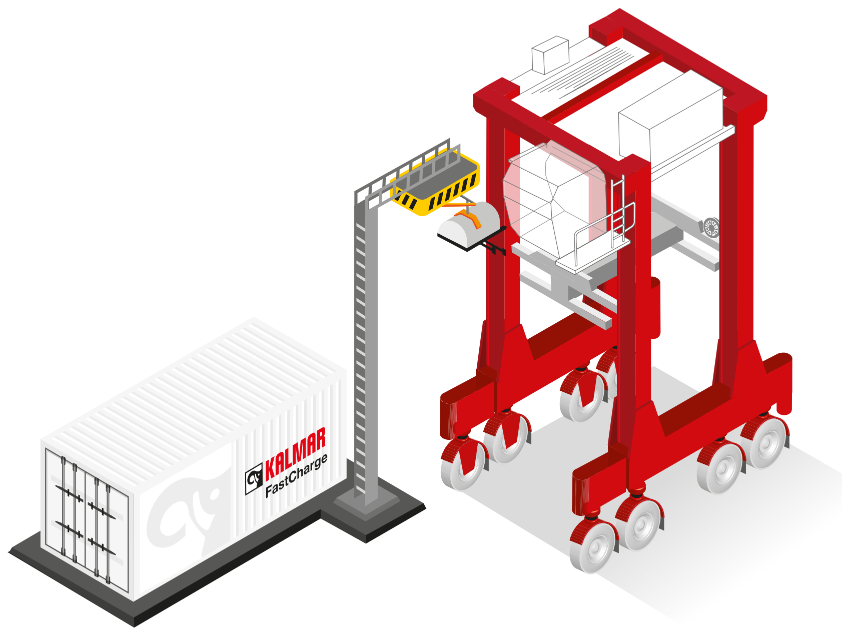
ELECTRIFICATION, CHARGING SOLUTIONS AND OPTIMISATION

At the time of writing (2023), arguably the most important trend facing terminal operators is the electrification of container handling operations. ASCs have always been electric therefore they can be seen as the baseline which to compare alternative technologies as terminals seek to reach zero on-site emissions and energy savings for their operations.

For horizontal transportation systems, hybrid straddle carriers have served as a successful interim solution that has significantly reduced energy consumption and emissions compared to traditional diesel machines. However, the full eco-efficiency benefits will be realised with the next generation of electric straddle carriers which will enable the AutoStrad solution to compete fully with ASC systems in sustainability metrics.

AutoStrad terminals differ radically from traditional manually operated terminals in that they are able to operate continuously on a 24/7 basis. The high power battery with FastCharge™ technology is currently the most promising option for electrifying straddle carrier fleets, as it enables the machines to be charged in short periods at suitable times between work tasks. This allows the machines to operate with optimum efficiency and minimises the impact of charging on the fleet availability rate. The Kalmar One automation system already supports electrification, enabling charging cycles and routes to be designed into the scheduling and optimisation of the equipment fleet.

At the time of writing, fully electric straddle carriers are already available but are not yet proven in automated operations. However, as electrification progresses in the global logistics industry, it is reasonable to expect that all investment decisions for future greenfield terminals will be based on all-electric fleet concepts. This will require significant planning for designing the charging infrastructure and managing the peak power consumption of the terminal; however, these concerns are somewhat mitigated by the fact that ports and terminals are typically sites that already have high-capacity power grid connections. Intelligent decision making provided by Kalmar One Fleet management serves to decrease the peak power demand on the grid, as the machines will typically charge at different times.



FastCharge™ enables machines to be charged in short periods at suitable times between work tasks.

SAFETY AND ACCESS CONTROL

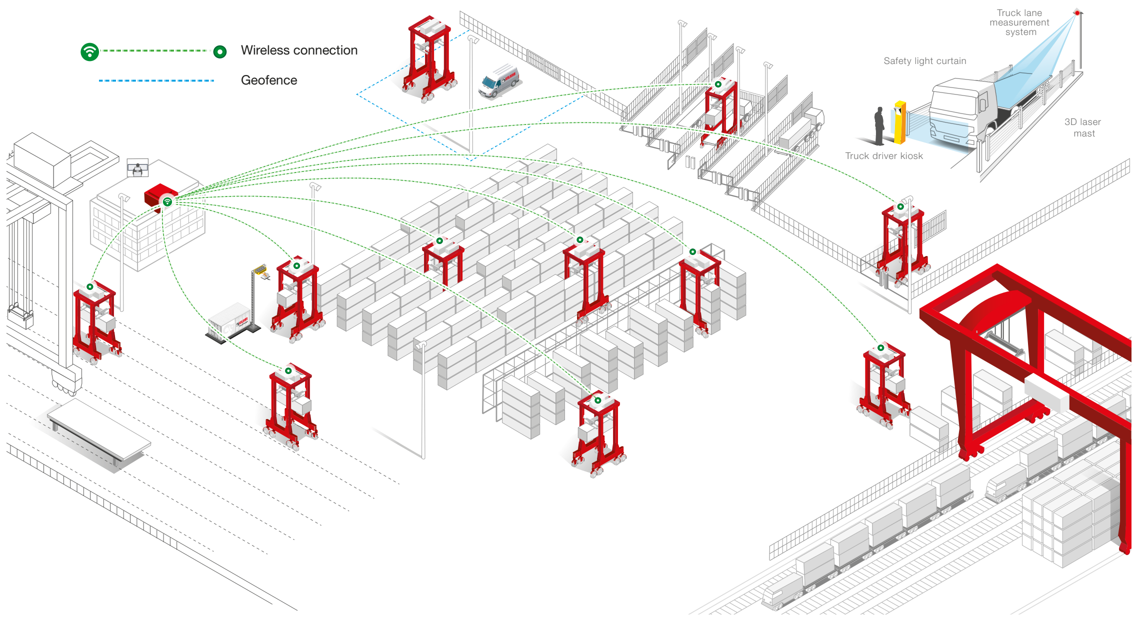
Automated straddle carriers offer a horizontal transportation solution that is well suited for medium-sized, large and very large container terminals. The larger the automated terminal, the more critical it is to be able to digitally geofence designated areas of the container yard in case of exceptions or repairs.

Straddle carriers are reliable, but with fleet sizes of dozens or even hundreds of machines, unplanned maintenance events may occur. For example, a single straddle carrier might need to stop as a result of a technical issue once or twice per year, at a terminal with 150 machines this means that there will be a machine that needs addressing almost every day somewhere in the terminal.

Automated terminals must have a reliable and safe way of restricting the movement of the machines in certain areas to permit personnel to enter the area, while simultaneously allowing the operation of the terminal to continue uninterrupted around it. It's worth noting that this functionality is required not only for maintenance of the automated machines, but also to enable other routine tasks ranging from pavement work to repairs on broken containers, lights or other terminal infrastructure. Additionally there is yard and quay crane maintenance to consider.

The geofenced areas can be static areas of the yard from which the automated machines are temporarily or permanently excluded from, or they can be dynamic zones that change depending on the situation, for example to keep other equipment out of the way of a moving quay crane. Geofenced safety areas also allow for more efficient use of the terminal land area, as the residual risk zone required by the automated equipment can be smaller than with traditional solutions.

One of the great advantages of an automated straddle carrier terminal is its redundancy. With a fleet of dozens or hundreds of machines handling the horizontal transportation and stacking of containers, an issue such as a door falling off a damaged container will, at worst, only result in a single machine standing in the yard in a geofenced zone as other traffic carries on around it. By contrast, the same scenario on an ASC would result in thousands of containers being locked in the stack served by the crane until the issue is resolved.



3 Terminal Modernisation

Kalmar AutoStrad can be deployed to many different terminal environments. For existing straddle carrier terminals a conversion to AutoStrad would be an obvious direction when modernising their operation. Also for other types of terminals, for example terminals operating rubber-tyred gantry cranes, conversion to a terminal concept based on automated straddle carriers is a very feasible option. A further enabling factor for megaterminal operation has been the four-high stacking capacity of the latest generation of machines. Moreover, automated straddle carriers require neither space for transfer points at the waterside in the same fashion that an ASC requires, nor the long truck lanes and wheel paths of RTGs, the land area available for container storage can be maximised.

For RTG terminals, converting to AutoStrad operation offers several advantages over automating existing RTG stacks and terminal tractors. All operations can be automated at once with a single type of equipment, and the safety of external truck drivers improves significantly since they don't need to drive inside the container stacking area. AutoStrad conversion also provides a lower initial investment for automating the terminal.

In the event that further storage capacity is required, a viable option is to build the fully automated AutoStrad operation first and then add additional stacking capacity with an ASC block within the automated zone. In this scenario, the external container handling interfaces remain exactly the same, while enabling optimal usage of the terminal land area. These kinds of hybrid terminal concepts are already in use at several major terminals around the world.

Another crucial consideration when comparing ASC and straddle carrier terminal concepts is that maximum capacity does not translate directly to maximum efficiency or throughput. At many terminals, it is not possible to obtain information in advance on when a specific container will be needed at the landside, so the container needs to be retrieved whenever the road truck arrives for the pickup. The capacity increase gained with higher stacking will result in a dramatic drop in productivity as time is lost on unproductive rehandling moves.

At straddle carrier terminals there is a relatively low percentage of non-productive container moves, as the containers are more easily accessed.

By contrast, at straddle carrier terminals there is a relatively low percentage of non-productive container moves, as the containers are more easily accessed in the straddle carrier stacks. The AutoStrad fleet can be shifted easily between the landside and waterside when needed, whereas at an ASC terminal half of the container handling capacity is always allocated to the waterside and half to the truck lanes.

To further streamline landside operations, some of the most advanced terminals have already adopted truck appointment systems in which truck drivers can pre-book their container pickup times. This ensures that the right container can be retrieved beforehand so that it will be immediately available for loading at the appropriate time.

TIMEFRAME FOR CONVERSION

The time required for the conversion of a manual straddle carrier terminal to automated operation depends greatly on the specific design, needs, operational environment and business goals of the terminal. However, a typical timeframe for an automation conversion project can be 12 to 18 months. This is significantly faster than the two to five year lead time that is required for new terminal projects based on gantry crane concepts.

A key factor that further shortens the deployment time for AutoStrad solutions is the ability to carry out the full range of integration and testing tasks at the factory. As a result, both the machines and automation system are delivered fully operational, allowing them to start generating an immediate return on the investment after arriving on site.

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When planning the conversion time frame, there are many ways to reach the end goal. The focus may be to carry out very comprehensive testing of systems through all possible scenarios, carrying out extensive training programs for all personnel involved in operation and preparing to the go-live in all possible ways. Or alternatively the focus can be to carry out the project in a swift way, and accepting the fact that some challenges will be faced during go-live and first operational months due to issues found or lack of appropriate skills within the existing workforce.

MANAGING THE TRANSITION PERIOD

In any automation project, a key priority is conducting the conversion with minimal disruption to the existing operations of the terminal. This requires careful advance planning, as an automated straddle carrier terminal typically needs to be automated in one go. Once the decision to automate is made, the project needs to be executed on a predetermined schedule, as it is not desirable to have an in-between situation in which part of the yard is automated and part of it is operated manually. The actual implementation can be done in several phases so that the operation is kept running continuously, but the process should be completed as swiftly as possible.

The transition will also most likely require changes to the terminal layout and operating procedures. The procedures for ship-to-shore (STS) operation, landside interfaces and reefer operation will be changing completely. Alternative processes may need to be introduced to handle non-standard cargo that cannot be taken into the automated area, as well as for empty container handling.

Change management of the workforce needs to be taken into account from the very beginning. The professional profile of the people operating and managing automated equipment will be markedly different from the staff running a manual terminal. Completely new skill sets are needed, and maintenance standards will need to be revised thoroughly.

TRANSITION TO AUTOMATION AREA BY AREA

At a container terminal, suspending operations for a long period of time in order to upgrade the horizontal transportation fleet or terminal design is obviously not an option. As a result, the options for automating an existing terminal are either a "big bang" approach in which the entire terminal is switched over to a fully automated solution that has been deployed, tested and simulated beforehand, or an incremental approach in which the terminal is automated one area at a time.

The options for automating an existing terminal are either a 'big bang' approach or and incremental approach.

The AutoStrad solution enables both options but the choice will ultimately depend on the specifics of the terminal. The key consideration is that simultaneous operation of manual and automated equipment in the same area is not likely to be a feasible option. A mixed operation environment would require lower operational speeds and introduce unpredictable variables as it is not possible to know exactly what manual operators do at each moment. As a result, the operational efficiency of the system would degrade significantly if automated machines would need to be prepared for any possible action by the manned machines, and would need to keep commensurately long safety distances.

4 Infrastructure

An automation conversion will require changes to the entire infrastructure of the terminal. These changes need to be planned from a wide perspective, not just focusing on the horizontal transportation equipment. Areas to consider include:

- terminal layout
- fencing, safety infrastructure, access control
- positioning infrastructure for the straddle carriers
- automatic/manual interchange points (waterside interface, truck and rail handovers, maintenance areas, empty container interchange, handling of reefers)
- IT environment and wireless networks
- yard lighting.

SEPARATING PEOPLE AND MACHINES

BE SAFE

The number one consideration in an automated terminal is maintaining strict separation between automated operations and areas in which people work, and designing safe and functional interfaces between the two. All non-standard cargo that requires manual handling has to be kept out of the automated operating area.

When handling exceptions, for example, strict safety protocols must be developed for all activities that involve people moving in the same area as the automated horizontal transport equipment. Particular attention needs to be devoted to the establishment of safety procedures and access control in areas with mixed auto/manual operations (maintenance, refuelling, washing, reefers, etc).

TERMINAL LAYOUT AND EQUIPMENT

In a typical container terminal, various facilities will be spread out across the site, either by original design or simply due to the organic growth and evolution of the terminal over several years. In an automated terminal, all facilities requiring mixed auto/manual operation will need to be sited at or relocated to the perimeter of the automated zone, in order to keep the automated area to a practical shape and guarantee smooth access of people to the area without disturbing other operations. Access control, safety systems and physical fencing for these functions needs to be considered when planning the automation conversion. Whenever possible, areas where automated vehicles and manned equipment need to cross each other's wheel paths should be avoided in the terminal design.

Alongside the automated straddle carriers, other terminal equipment may require upgrades or new functionality in order to interface with the straddle carriers. This includes instrumentation to provide accurate and reliable position measurement; various sensors; and additional control system layers for ship-to-shore and rail cranes.

WIRELESS INFRASTRUCTURE

An automated straddle carrier terminal will require the installation of a site-wide wireless network for communication with the straddle carriers. As 5G technology has become more widespread, it has become a viable option for managing the site-wide data traffic required by the automation infrastructure. The exact details will vary on a country-by-country basis, but Kalmar has a tested private 5G solution that is already available for AutoStrad terminals.

PAVEMENT WEAR

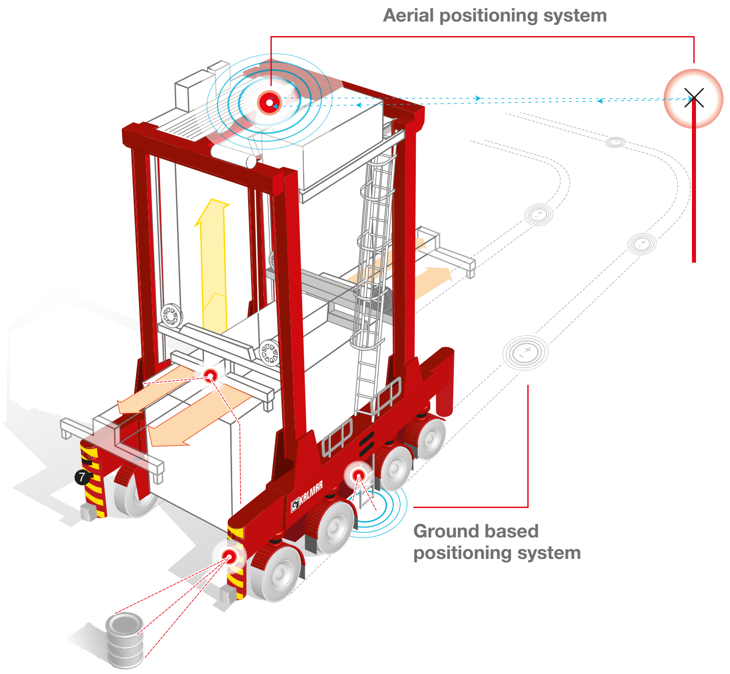
Automated straddle carriers can help extend the lifetime of the pavement at the terminal. As automated machines are driven on pre-planned paths with centimetre-level precision, the driving routes can be programmed to enable more even wear on the pavement in the yard. If practical for the location and climate conditions, laying a concrete surface for the yard will typically provide the most durable surface for operation.

Wear on the pavement can be reduced by 'stack shuffling', in which the position of the container blocks is shifted continuously in increments of a few centimetres.

In the container stack, wear on the pavement can be reduced further with so-called stack shuffling, in which the position of the container blocks is shifted continuously in increments of a few centimetres, first in one direction, and eventually back. This level of precision in container placement can double the pavement lifetime compared to traditional manually operated straddle carrier terminals. In manual terminals, the container rows are marked on the yard surface with paint, which means that the yard surface will be worn in the areas where the wheels continuously travel. In automated terminals, the stack locations are defined only on a virtual map, which is continuously applied with an offset that results in even wear of all parts of the yard, thus increasing its lifetime.

POSITIONING TECHNOLOGY OPTIONS

Automated straddle carriers require a positioning system that can reliably and accurately determine the position and orientation of the automated vehicle in the operating area. The two broad categories of positioning systems that are currently relevant for automated straddle carriers are aerial systems that include radar or pseudo-satellite systems, and ground-based RFID solutions. Both offer location accuracy of under a few centimetres with high reliability, and have been proven in actual terminal operations. The best option is always determined by the individual needs of the terminal and is provided as part of the overall package.



Aerial positioning systems
Radar navigation is based on a network of passive radar beacons installed around the terminal yard. For a typical container terminal, 100 to 200 beacons will be installed on the site. A radar unit on the top of the straddle carrier tracks the position of these beacons. Navigation requires a line of sight to at least three beacons at any given time, which is normally easily achieved.

Compared with ground-based RFID solutions, a radar positioning system requires a relatively small infrastructure investment. The individual radar beacons are inexpensive and can be easily installed, for example, on lighting towers. An added benefit of radar is that the equipment is located high on the straddle carrier frame where it is more protected from wear and tear. Radar navigation works on any type of pavement surface.

A second aerial positioning option for Kalmar AutoStrad is the Locata pseudosatellite system that is based on a network of terrestrially based transceivers that transmit extremely well-synchronised signals. These signals form a positioning network that can operate in combination or without GPS to provide highly accurate positioning with simple receivers that only utilise one-way ranging signals.

Ground-based solutions
As an alternative to aerial positioning systems, Radio-frequency identification (RFID) transponders manufactured by BTG can also be used as the positioning solutions for Kalmar AutoStrad. In order to determine the position of the vehicle, the system uses transponders installed in the site pavement and antennas on the vehicle.

An RFID transponder is an electronic device that produces a response when it receives a radio-frequency interrogation. A transponder does not have an internal power supply, so in order to transmit the programmed data it is charged by the antenna installed on the vehicle.

The transponders are installed in a grid pattern in the pavement. Various installation options are available depending on the mounting depth and material in which the transponder is installed.

SOFTWARE INTEGRATION

Automated equipment is only as good as the software controlling it. To obtain the desired performance from automated horizontal transport equipment, the terminal's TOS (Terminal Operating System) and other systems must be up to the task, and designed to fulfil seamlessly the required business processes while providing efficient ways to handle exceptions.

Automated equipment is only as good as the software controlling it.

An efficient automated terminal requires that business processes are mapped carefully. Software integration needs to take place at all levels, from yard equipment to process automation. The complete system design, including all subsystems, has to be implemented according to a single set of business processes and exception scenarios, where the roles and interfaces between the subsystems are clearly specified.

Smooth and efficient deployment of new technology in an automation project requires thorough testing and emulation to ensure that all subsystems form a solution that complies with planned business processes. The execution of all business processes has to be confirmed first in an emulation environment where all production subsystems are present and end-to-end scenarios have to be verified.

Kalmar offers a comprehensive digital twin environment that runs an authentic terminal logistic system with simulated vehicles. Complex deployments can include a number of production software versions and releases from multiple vendors, which can all be tested beforehand with actual terminal data.

OFFBOARD VS. ONBOARD AUTOMATION

Kalmar's approach to automation of horizontal transportation at container terminals is based primarily on advanced offboard automation in which the centralised software solution handles the scheduling, routing, resource allocation and control of the entire equipment fleet. The system keeps track of the real-time position of every straddle carrier and provides one machine at a time with the right to operate in a given physical zone within the terminal. The centralised solution also handles communication with the TOS, as well as the interfaces with STS cranes and other external third-party systems.

Kalmar's approach is based primarily on advanced offboard automation in which the centralised software solution handles the scheduling, routing, resource allocation and control of the entire equipment fleet.

Container terminals are by default closed, controlled environments in which optimum performance for automated systems is realised through centralised control of all assets. In a Kalmar AutoStrad terminal, the machines determine their exact position and orientation, and use routing information provided by the offboard automation to carry out the required tasks.

An exception to this may be future mixed mode terminal concepts in which automated and manual equipment operate in the same area. In Kalmar's view, this is not an ideal scenario for straddle carrier terminals, as fully automated AutoStrad operation will always provide the best results. However, mixed mode scenarios might in some instances be useful for operators running fleets of terminal tractors.

SAFETY AND SECURITY

Safety is always paramount in any terminal operation. Automated terminals provide significant improvements in occupational safety by keeping people out of the operating area of moving heavy machinery.

Since the introduction of the Kalmar AutoStrad™ system in 2005, the Patrick container terminal in Brisbane has become one of the safest in the world. The Lost Time Injury Frequency Rate (LTIFR) and Medical Treatment Injuries (MTI) rates have reduced dramatically in the facility as a whole, and after 18 years of operation, there have been no LTIFR or MTI incidents that are attributable to the use of the automated equipment. In the 2022 financial year, the LTIFIR and MTI rates at the terminal remained c. 80% and more than 90% lower, respectively, since the years prior to automation. These results have been maintained concurrently with a growing volume of freight over the years.

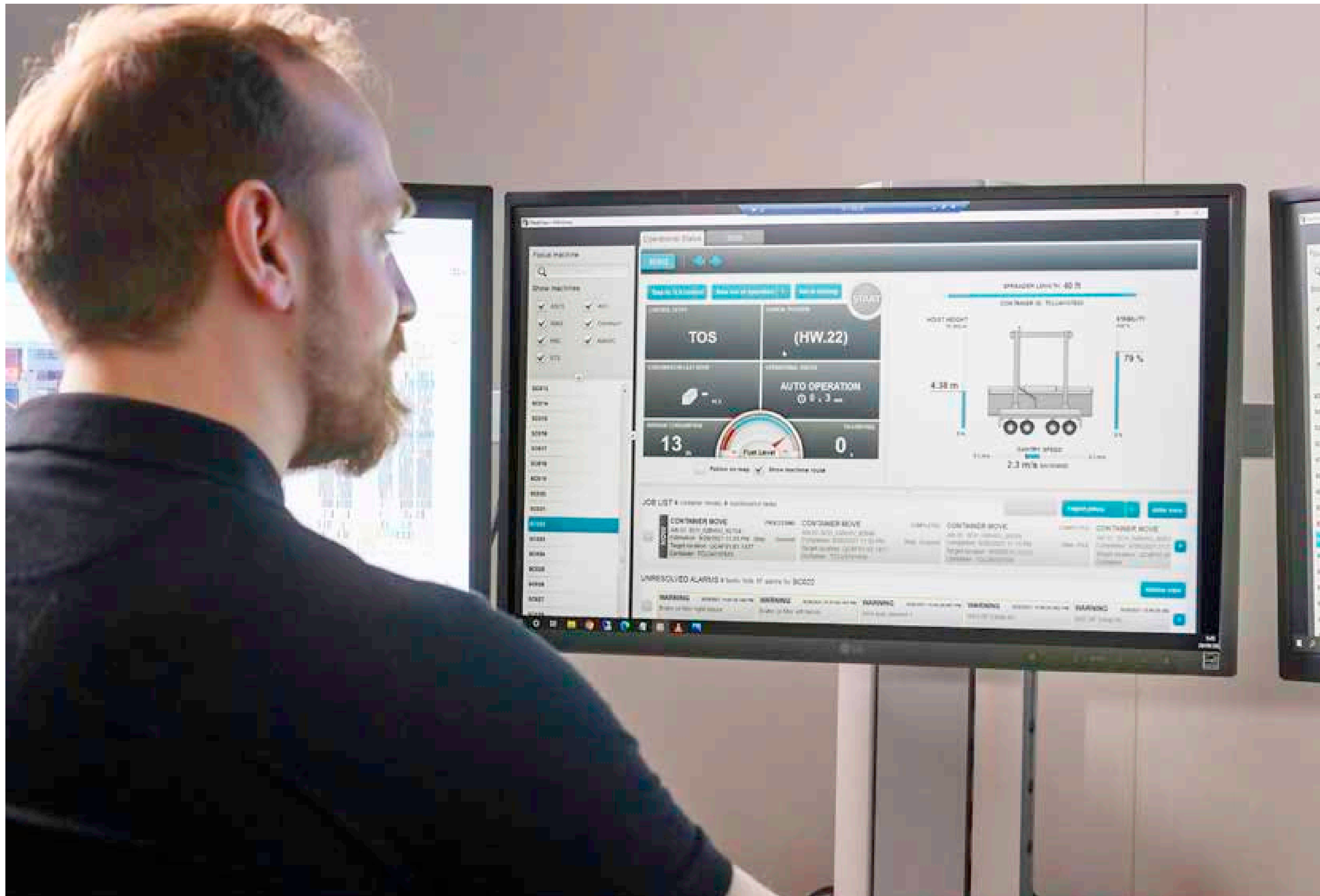
From the safety perspective, a straddle carrier terminal is relatively straightforward to automate, as segregation of people from the automated areas is part of the concept. Unlike in RTG operation, where manned trucks are operating in the crane stacks, with automated straddle carriers the trucks can be handled in their specific areas, where they do not interfere with automated operation. However, in addition to infrastructure and terminal layout considerations, a different kind of safety mindset will need to be instilled throughout the workforce. Adoption of safe working procedures for accessing the automated area is required. Employees will also need to be trained locally – a safety handbook alone in English will not be enough.

Automated terminals improve the security of both cargo and personnel thanks to automated container handling and location tracking.

An automated terminal will bring about a major change in the overall working conditions of operating staff. By transitioning to indoor desk work, employees will no longer need to work outdoors exposed to noise and other emissions, cold and heat, bad ergonomics or vibrations.

Furthermore, automatic driving eliminates collisions and accidents in the container yard, which will decrease the insurance premiums of the terminal. The Patrick container terminal in Brisbane has reported savings in workers' compensation costs due to improved occupational safety.

Automated terminals improve the security of both cargo and personnel thanks to automated container handling and location tracking of all containers. Containers are not accessible by people in the automated zone and cannot be set down in unauthorised areas. All container moves leave a trace in the system, and therefore any unauthorised move of containers can be identified. Increased security contributes to customer trust and terminal competitiveness while reducing financial losses.



5 Maintenance and support

A CHANGE IN MINDSET

With automated operation the emphasis shifts to more frequent preventative maintenance. However, this maintenance is usually done at planned intervals.

Manual horizontal transportation systems will work even if the equipment is not in perfect condition, since human operators can usually compensate for the quirks and deficiencies of each individual piece of equipment. By contrast, automated equipment always needs to be in 100% optimal condition to deliver its full potential.

This requires a major change in attitude and culture for maintenance operations. With automated operations, the emphasis shifts to more frequent preventive maintenance. However, as this maintenance is usually done at planned intervals, the caused impact to the operation is minimal. As collisions and other accidents due to human error are eliminated, the need for ad hoc repairs is also reduced dramatically, bringing cost savings in the long term.

To summarise, automated machines need to be maintained more carefully and more often. At the Patrick container terminal in Brisbane, maintenance savings from more efficient equipment use have been calculated at over 300,000€ per straddle carrier over the service life of the machine. At the same time, the equipment lifetime of automated machines has increased 30% compared to straddle carriers used in manned operation.

SYSTEM UPDATE AND OPTIMISATION

In today's highly complex automation systems, regular software updates are a key part of operations. Kalmar has significantly enhanced its software maintenance model, enabling faster updates with consistent deployment throughout the customer's environment. All software can now be tested thoroughly beforehand in a digital twin, based on actual customer-specific data.

The software maintenance model is also connected with continuous system optimisation that allows the terminal to gain the optimum performance from the automation system. Based on real-world data, Kalmar's experts can help analyse the performance of the terminal and find areas for improvement together with the terminal operator's own experts.

Software updates are also crucial to ensure cybersecurity.

Software updates are also crucial to ensure cybersecurity. Not all of the security patches may be related to the actual automation system software but concern security updates for the underlying operating systems and third-party software components. The terminal must not only have access to the latest patches and software versions, but also ensure that all systems are actually updated. In recent years, terminal operators have become more aware of the need for consistent cybersecurity processes, and expect system vendors to report proactively on any vulnerabilities that are discovered in the industry.

The ISA/IEC 62443 series of standards define requirements and processes for implementing and maintaining electronically secure industrial automation and control systems. These standards set best practices for security and provide a way to assess the level of security performance. These standards are designed to bridge the gap between operations and information technology as well as between process safety and cybersecurity.

Kalmar has gained certification of its KalmarOne automation system development processes according to the ISA/IEC 62443-4-1 standard. This means that Kalmar's processes and practices to develop, release and test the product have demonstrated that it follows and meets the standard.

The new EU machinery directive that was approved in July 2023 also includes requirements for cybersecurity. The regulation will become mandatory from 2027 for all machines and systems in the EU, therefore compliance with the relevant standards will become an obligation for system vendors.

6 Business impact

If automation is built with a 'bits and pieces' approach, the terminal may save in the short term, however these savings can be lost quickly at the deployment stage.

INTEGRATION CHALLENGES

A key consideration in an automation project is its implementation time. On one hand, terminals seek to minimise the cost of conversion, often by combining components from multiple vendors. On the other hand, every interface between two systems needs to be carefully designed, integrated and tested, and can be laborious to maintain. Simply optimising for the cost of individual subsystem components can be a shortsighted approach.

If automation is built with a "bits and pieces" approach, the terminal may save in the very short term, however these savings can be lost quickly at the deployment stage due to the added complexity of integration and a slower ramp-up of productivity. In contrast, a vendor that can offer a completely integrated turnkey solution will be able to provide a system that is not only possible to deploy faster, but is also more cost-effective as a whole, while providing lower lifetime maintenance and support costs. The simpler the overall system and the fewer interfaces that need to be integrated and tested, the faster the implementation.

BENEFITS OF EARLY ADOPTION

Compared with numerous other fields, automation is still a new development for the container terminal industry. Automation adoption rates vary greatly from geography to geography, and terminals will look to the automation level of other terminals on the same trade routes and/or in the same region.

Competitive advantage is available for first movers that adopt automation sooner than their competitors. Conversely, without automation, terminals will inevitably fall behind against automated terminals in the same region. In the worst case, this may even mean the end of business for the terminal.

Early adopters reap the biggest benefits of automation, as they can finance the productivity-increasing automation investment with cash flow from existing manual operations. Once the automation investment is finalised, they can attract more business to their terminal. By contrast, the late adopters will be risking their capacity to stay in business as they have to finance their automation investment with potentially decreasing cash flows due to the increased competitiveness of new automated terminals.

For greenfield terminals, automation is already the norm rather than the exception. It is highly unlikely that any major new terminals will be built for traditional fully manual operation. For existing terminals, the benefits of automation are equally clear, and over the next few years these benefits will be reaped by forward-looking operators seeking to stay ahead in today's intensely competitive global container shipping industry.

TOTAL COST OF OWNERSHIP: MANUAL STRADDLE CARRIERS VS. AUTOSTRAD

Automated straddle carriers are suited to nearly any type of container handling operation from marine and intermodal terminals to logistics parks. In principle, there is no upper limit on the size of terminal that can be served by the AutoStrad concept, and the system can bring benefits to all but the very smallest manually operated terminals.

When comparing various terminal concepts, the AutoStrad system is by far the most economical option both in terms of capital investments and lifetime costs. Automation offers clear financial advantages, and the exact numbers (OPEX, CAPEX, EAC, payback time, ROI) should be calculated, taking into account the terminal operator's cost structure. Savings in salary costs are the simple and immediately obvious benefit that is easy to calculate together with the automation vendor.

For more detailed long-term projections, the terminal is always the best placed expert on its own operations. Automation projects always revolve around a basic wishlist – an idealised implementation that encompasses the swiftest possible deployment, maximum performance improvement, and an integrated turnkey solution. Success in practice will depend on skilful optimisation of these and numerous other factors.

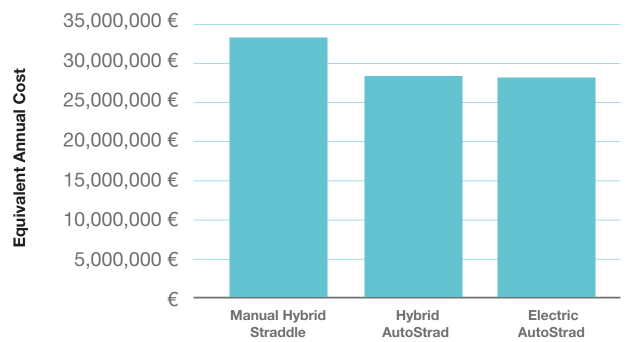
EVALUATING TCO

Total Cost of Ownership (TCO) has a significant role in automation investments. TCO calculations are without a doubt a good tool, however, the assumptions and scope behind the calculation have to be made clear for a terminal operator to verify the assumptions. The TCO for an automation system must take into account not only the container handling equipment but also the required civil infrastructure works, network infrastructure, TOS upgrades as well as the cost of capital and equipment lifetimes.

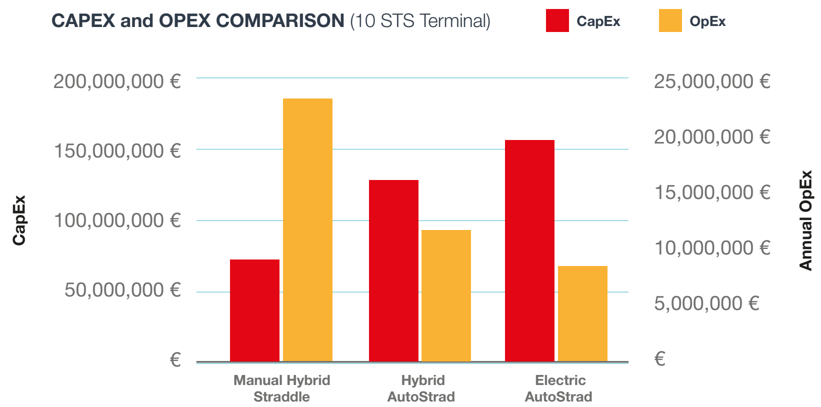
It is no secret that the upfront investments for automation are significantly higher than for manual equipment. However, what the investment offers is significant cost savings and – more importantly – clear visibility to future operations. In an automated environment, there is no longer a need to, for example, decrease operational intensity during the night, so business can keep going around the clock, even during the times that would be most expensive for a manual terminal.

TCO comparisons between a manual straddle carrier operation and the AutoStrad concept will almost certainly ultimately favour the AutoStrad in high labour cost areas where the terminal operates at high intensity. Investing in the AutoStrad means a higher CapEx investment but significantly lower OpEx costs; however, it is important to note that the higher investment costs also offer a longer equipment lifetime as the AutoStrad is not subject to the same wear and tear as manual equipment.

EQUIVALENT ANNUAL COST COMPARISON (10 STS Terminal)



CAPEX and OPEX COMPARISON (10 STS Terminal)



TCO for Manual Straddle Carrier and AutoStrad™

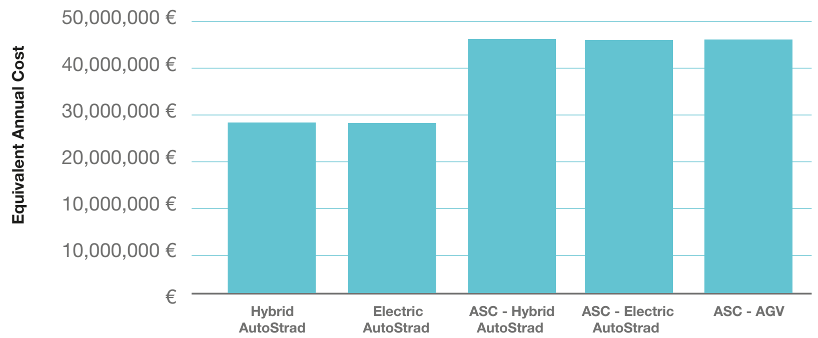
To ensure the comparability of different solutions we prefer to use the CapEx and OpEx cost split as well the Equivalent Annual Cost (EAC) that annualises the CapEx for each solution factoring in the cost of capital, equipment lifetime as well as annual OpEx costs.

On a comparable basis, the AutoStrad offers annual cost savings of over 13% when compared to the manual straddle carrier operation. However, it is important to note that this number can be significantly higher for terminals in North America or Oceania. The cash flow profile differs quite significantly from a manual straddle carrier, as CapEx is around 2 x higher, but OpEx is over 50% lower.

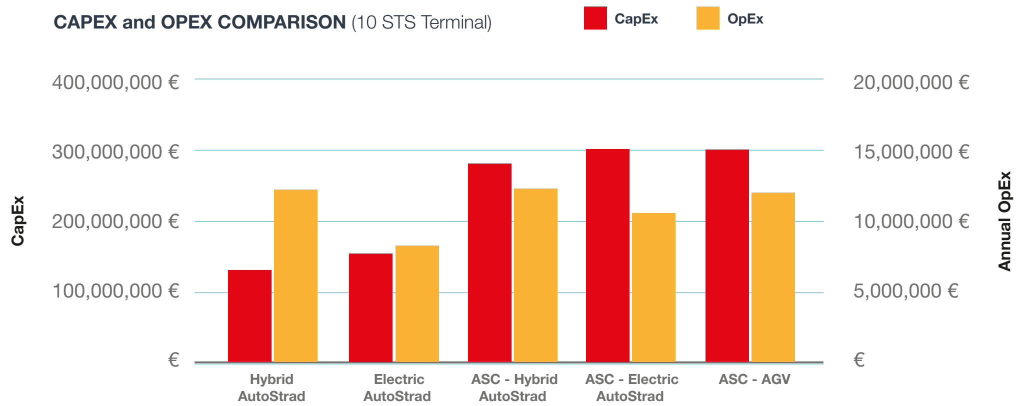
On a comparable basis, the AutoStrad offers annual cost savings of over 13% when compared to a manual straddle carrier operation.

The calculation reflects conditions of a European container terminal that operates with 10 Ship-to-Shore (STS) cranes. The EAC analysis assumes a weighted average cost of capital of 10% and an equipment lifetime of 12 years for the manual straddles and 15 years for the AutoStrad. For the electric solutions, we assume the worst case scenario during peak hours and there is no idle time, resulting in a 11% drop in productivity due to charging. The drop is compensated with a 11% larger equipment fleet, which can be assumed to be on the high side due to optimised opportunity charging done by the automation system.

EQUIVALENT ANNUAL COST COMPARISON (10 STS Terminal)



CAPEX and OPEX COMPARISON (10 STS Terminal)



TCO for AutoStrad™ and ASC solutions

Total Cost of Ownership: AutoStrad vs. ASC
The AutoStrad offers terminal operators an automation system that is light in infrastructure requirements compared to the Automatic Stacking Crane (ASC). This makes the AutoStrad System easy to deploy with the industry's best time to value and an attractive cash flow profile with relatively low capital investments. It is necessary to state that in return for the higher capital investment of the ASC, it does offer a longer lifetime than the AutoStrad, however, the investment case is often more rear-loaded as the breakeven is further in the future.

On a comparable basis, the AutoStrad offers more than 35% lower annual costs than the ASC solution. This difference is mostly attributed to the significantly higher CapEx of the ASC due to the larger required infrastructure and the need to have two container handling systems, one for stacking and one for horizontal transportation. This leads to a larger fleet of container handling equipment which is reflected in CapEx costs.

The calculation reflects the conditions of a European container terminal that operates with 10 STS cranes. The EAC analysis (on the right) assumes a WACC of 10% and an equipment lifetime of 15 years for the AutoStrad, 25 years for the ASC and 20 years for the AGV.

7 Automation maintenance and support

Automation support services are available 24/7/365 to address any unplanned interruptions and incidents.

At automated straddle carrier terminals, maintenance and support can be divided between the equipment and the automation/software component of the solution. Maintenance of the actual machines is largely similar to traditional straddle carriers, although this is performed with a more pre-emptive, data-driven approach.

Support for the automation system can encompass updates to the automation software, remote support for the automation system, on-site automation personnel services, automation software deployment, and other professional services required by the terminal.

At Kalmar, automation software updates are based on quarterly new software versions with fixes, minor functionality enhancements, and compatibility updates. The software is tested with customer-specific release test environments, and the company's experts are available to answer any questions concerning the software.

Automation remote support services are available 24/7/365 to address any unplanned interruptions and incidents, while on-site automation personnel services can be tailored to the customer's needs depending on the level of support needed.

Additional automation support offerings include automation software deployment that covers remote software updates as well as on-site deployments. The scope of the deployment services can extend from minor configuration changes to entire system software upgrades, and can also cover testing and production environments.

Finally, professional services for automation help optimise the operations of the terminal, and provide emulation as well as training services for the automation system. When needed, bespoke development services are available to tailor the automation software, hardware and/or services based on the needs of the terminal.

8 Human resources

Automation is where IT meets engineering. In a traditional manual terminal, IT and engineering are typically two separate teams that have little contact with each other. With an automation rollout, these two need to start cooperating and form a joint team in which the skills and responsibilities of the people match each other and mutual responsibilities are clearly defined and agreed.

CHANGING SKILL SETS

Fleets of dozens of straddle carriers can be handled with only a few highly skilled operators.

The most significant and immediate cost savings from automation are due to the drastically smaller number of operators required. Fleets of dozens of straddle carriers can be handled with only a few highly skilled operators. An automated terminal also requires a significantly different profile of employee. A different level of maintenance engineer skills is also required for the stricter maintenance standards of automated equipment. In addition, automated operations will require new, different skill sets in several other areas, including:

- data and fact-based usage and analysis compared to operators reporting faults in equipment
- data mining
- understanding the operating principles of automated equipment and systems
- competence in measuring and sensor technology that replaces the human senses
- systematic planning of operation and maintenance work.

New jobs that will need to be outsourced or insourced include automation system specialists; system optimisation engineers; IT system service and maintenance professionals; and instructors for internal staff and external parties. Conversely, significantly fewer employees will be required for basic container operations and traditional maintenance tasks.

Successful change management requires an open dialogue between all relevant parties.

NEED FOR OPEN DIALOGUE

Conditions, legislation and industry labour standard practice differ greatly from geography to geography. In many locations, limited availability of skilled personnel – even at competitive salaries – can also present a challenge. Automation resolves this issue, but also changes the profile and structure of the terminal staff.

Successful change management requires an open dialogue with all relevant parties. Human resources need to be taken into account from the beginning. Automation provides new job opportunities, but also places additional demands on the workforce.

The significant workforce impact of automation needs to be considered and planned carefully, working in cooperation with local labour organisations and other stakeholders.

CHANGE MANAGEMENT

An often overlooked or underestimated fact is that automation is foremost a major culture change in how a terminal operates. For an automation deployment to be successful, managing this culture change is more crucial than the technical implementation.

The job profile of the workforce will be transformed, a new maintenance approach is required, IT and engineering operations will need to converge, and business processes will need to be mapped and planned far more carefully than before. Whether creating a new automated terminal or converting a manual terminal to automated operation, change management is critical.

ABOUT KALMAR

Kalmar, part of Cargotec, offers the widest range of cargo handling solutions and services to ports, terminals, distribution centres and to heavy industry. Kalmar is the industry forerunner in terminal automation and in energy efficient container handling, with one in four container movements around the globe being handled by a Kalmar solution. Through its extensive product portfolio, global service network and ability to enable a seamless integration of different terminal processes, Kalmar improves the efficiency of every move.

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KEEP IN TOUCH WITH US

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Tomi Tuulkari works as Director, Product Management in Kalmar. Tomi's original automation expertise comes from delivering multiple Automated Stacking Crane projects. He is passionate about customer collaboration, product management practices and ensuring that the developed automated equipment fulfils the needs of the industry and that it can be maintained easily over the lifetime of the product. Today, Tomi leads the Product Management team dedicated to Kalmar AutoStrads. He spends his time communicating with Kalmar's customers and partners, steering product development, as well as designing and scouting new technologies that can help customers operate automated sites even more safely while increasing productivity.

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Jarkko is the Head of Automation Sales in Kalmar. He has over 15 years of experience in the terminal industry and automation. Jarkko has worked in several director roles at Kalmar including roles in project and product management as well as in sales. Jarkko is a proud father of four children and a passionate triathlete, determined to improve and challenge himself both mentally and physically. He has an MSc degree in Automation Engineering from Tampere University of Technology and is currently working on his MBA at AaltoEE.

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WP-AUTOSTRAD-WW-EN / 2023-10-20