



Conversion to automated straddle carrier terminal

Converting a manual straddle carrier
terminal to automation

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Automation is the next step towards improving performance

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

In this paper, we examine several of these areas, ranging from the financial impact of automation to terminal and infrastructure design as well as technology options. Finally, we will look at proven results in the field.

1. Why automated straddle carriers?

1.1 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 compared to other terminal concepts include flexibility and simplicity. In a straddle carrier terminal, a single machine handles both stacking and horizontal transportation. Other horizontal transportation concepts, such as those built around automated guided vehicles (AGVs), will always need another machine to stack the containers and load landside transport vehicles.

A straddle carrier terminal can adapt easily to changes in terminal throughput. Excess machines are automatically parked away when not needed, and more equipment will be added on demand.

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



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automated straddle carrier terminal in the future, one or more ASC blocks can be added to increase the stacking density.

1.2 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, 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 handled optimally. Collisions due to human error and unplanned repair tasks are eliminated.

Automated equipment also conserves resources and contributes to the sustainability of resources. Significant fuel savings are realised through optimal driving patterns, a reduced need for air-conditioning, 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.

2. Terminal implications

2.1 TIMEFRAMES 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. ►

” Key priority is carrying out the conversion with minimal disruption to the existing operations of the terminal.

When planning the conversion timeframe, a key consideration is whether to optimise for maximum testing of new systems or for the swift adoption of the new processes and organisational culture required by automated operations. A slower transition will enable more thorough technical testing and training of operational personnel, but a quicker transition may be preferable for organisational reasons.

2.2. MANAGING THE TRANSITION PERIOD

In any automation project, a key priority is carrying out 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.

The transition will also likely require changes to the terminal layout and operating procedures. The procedures for ship-to-shore (STS) operation, landside interface and reefer operation will be changing completely. Alternative processes may need to be introduced also 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.

3. Infrastructure

3.1 THE BIG PICTURE

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 changes
- Fencing, safety infrastructure, access control
- Navigation 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

3.2 SEPARATING PEOPLE AND MACHINES

The number one issue in an automated terminal is maintaining strict separation between automated operations and areas in which people work, and designing safe 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 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.).

3.3. TERMINAL LAYOUT

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.

3.4. WIRELESS INFRASTRUCTURE

An automated terminal will require navigation infrastructure for the automated equipment. Typically this will be either radar beacons installed on lighting towers and buildings around the site, or magnetic markers embedded in the yard pavement (see section 4). Accurate and reliable position measurement for STS cranes also needs to be considered.

An automated straddle carrier terminal will require the installation of site-wide wireless network for communication with the straddle carriers. At least two additional radio frequency links will also be installed for emergency stop and long-range remote control functions.

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, sensors and PLCs (programmable logic controllers) for STS and rail cranes.

3.5 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 ERP (enterprise resource planning), TOS (terminal operating system) and other systems must be up to the task, and designed to seamlessly fulfil the required business processes while providing efficient ways to handle exceptions.

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. ►

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Smooth and efficient deployment of new technology in an automation project requires thorough testing and simulation 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 a lab environment where all subsystems are present and end-to-end scenarios have to be verified.

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

4. Navigation

4.1 NAVIGATION TECHNOLOGY OPTIONS

Automated straddle carriers will require a navigation system that can reliably and accurately determine the position and orientation of the automated vehicle in the operating area. The two practical options that are currently available are magnet and radar navigation. Both options offer location accuracy of under a few centimetres with high reliability, and have been proven in actual terminal operations.

Often an automated horizontal transportation and automatic stacking crane (ASC) system would be built using magnet navigation, and a pure automated straddle carrier terminal with radar technology. However, both are valid choices, and the best option is always determined by the individual needs of the terminal.

4.2 MAGNET NAVIGATION

Magnet navigation for automatic straddle carriers works by embedding a pattern of passive magnets in the pavement of the container yard. Sensors on the bottom frame of the straddle carrier detect these magnets and the control software determines the location and orientation of the machine.

Magnet navigation requires a relatively large one-time infrastructure investment in the installation of the magnets. By contrast, the equipment investment for each straddle carrier is relatively small. As the navigation equipment is located at ground level in the straddle carrier, it can be more prone to wear and tear during operations.

The individual magnets themselves are long-lasting and virtually indestructible, provided the pavement remains in good condition. However, an important question is how future refurbishing of the pavement will affect the magnet installation. The lifespan of the pavement can be maximised by automatic incremental shifting of the straddle carrier travel paths (stack shuffle).

4.3 RADAR NAVIGATION

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.

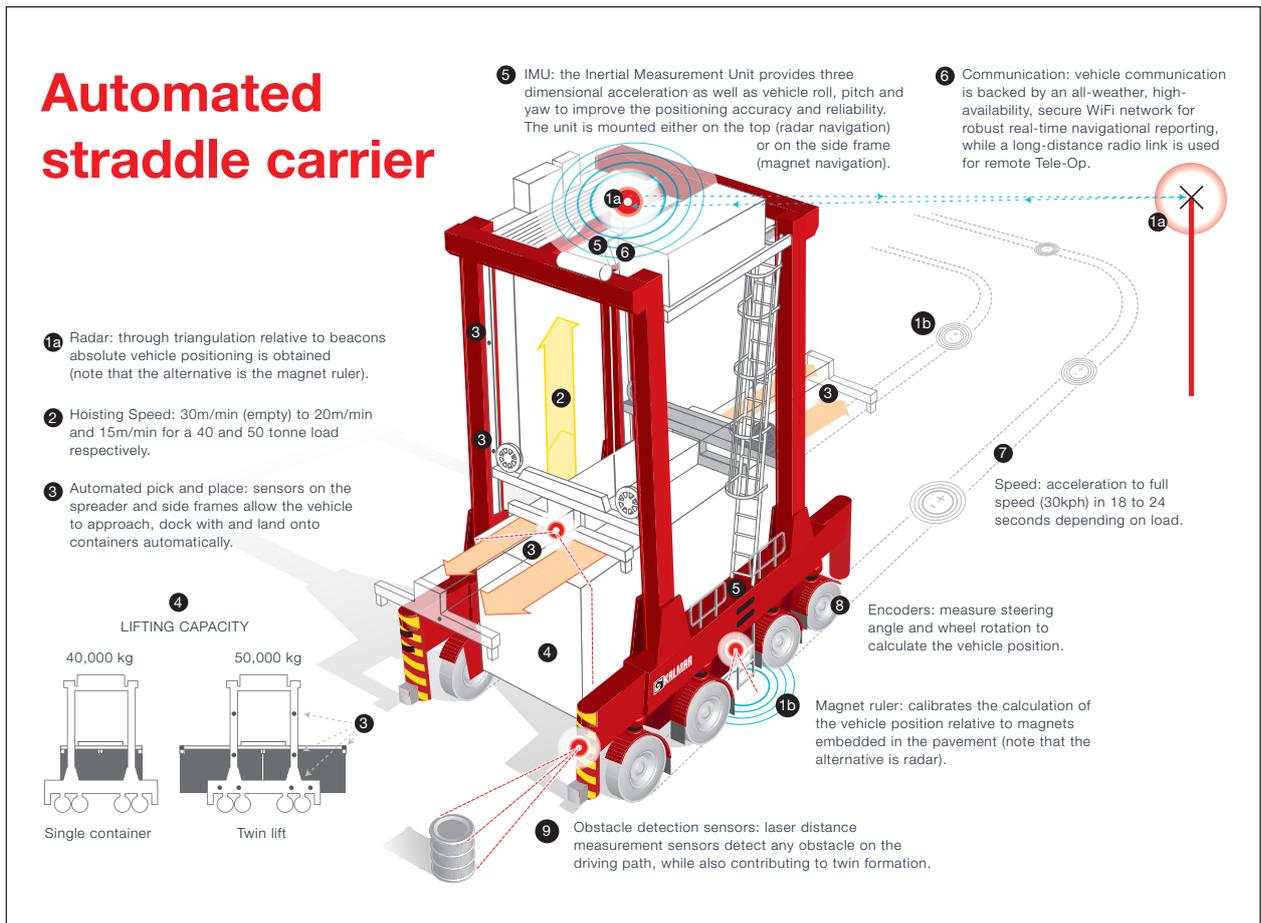
Compared with magnet navigation, a radar-based system requires a lower infrastructure investment. The individual radar beacons are inexpensive and can be easily installed, for example, on lighting towers. An added benefit of radar is that the equipment is located high on the straddle carrier frame where it is more protected from wear and tear.

Radar navigation works on any type of pavement surface. As with magnet navigation, stack shuffle functionality can be used to significantly extend the lifespan of the pavement in the container yard.

4.4 OTHER SOLUTIONS

Radio-frequency identification (RFID) is occasionally used as the navigation technology for automated horizontal transport equipment. However, compared to magnet and radar navigation, RFID offers no significant benefits and has several limitations.

Automated straddle carrier



RFID solutions require a major investment in both the yard infrastructure as well as the onboard navigation equipment. Transponders need to be programmed individually, which is a laborious process. The lifespan of the RFID devices is also limited, and the physically bulky equipment is not ideal for the slim bottom frame of a straddle carrier.

For the above reasons, magnet and radar navigation are currently the best options for automated straddle carrier terminals, with the optimum choice to be determined on a case-by-case basis.

5. 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. The Patrick container terminal in Brisbane has become one of the safest in the world since the adoption of the Kalmar AutoStrad™ system.

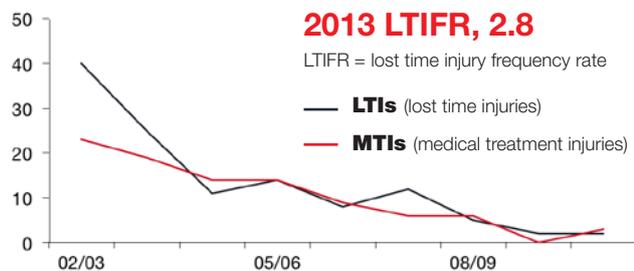
From the safety perspective, a straddle carrier terminal is relatively easy to automate since there are no manual truck lane operations as with an RTG terminal. However, in addition to infrastructure and terminal layout considerations, a different kind of safety mindset will need to be instilled throughout 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 in English is not enough.

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.

“In the first year of automation at our Brisbane AutoStrad™ Terminal, we achieved a 75% reduction in safety incidents, increasing to a reduction of 90% in following years. It is only logical that we look to replicate this success at our biggest container terminal at Port Botany.”

John Mullen, MD & CEO Asciano Ltd,
22/8/2012



This LTIFR number is calculated per 1,000,000 man-hours whereas other parts of the world use per 200,000 man-hours

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. Increased security contributes to customer trust and terminal competitiveness while reducing financial losses.

” Automated equipment always needs to be in 100% working condition to deliver its full potential.

6. Maintenance

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% working condition to deliver its full potential.

This requires a major change in attitude 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.

7. Automating existing equipment

The actual automation of most straddle carriers of recent models is relatively straightforward. Electric or hydraulic steering is controlled by onboard automation systems instead of from the cabin, while sensors and data links are added for control, monitoring and system diagnostics.

Kalmar straddle carriers are available with various automation readiness levels to meet the plans of terminals that are considering converting to automation at some time in the future.

Kalmar's automation solution is also suitable for use with any brand of straddle carrier. However, there are limits due to the age and type of straddle carriers that may not be practical and/or economical to automate. ▶

” Automation
is where
IT meets
engineering.

In any automation project, third-party or mixed fleets can create challenges in, for example, the division of responsibility in maintenance questions, access to proprietary system data, as well as guaranteeing performance levels for yard equipment. The best automation solution will always be based on the needs of the customer, but working with a fully integrated system from a single vendor – and upgrading the straddle carrier fleet when necessary – is often the most cost-effective solution for the terminal in the long run.

8. Human resources

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 by only a few highly skilled operators.

8.1 CHANGING SKILL SETS

Automation is where IT meets engineering. In a traditional manual terminal, these are typically two separate teams that have little contact with each other. With an automation rollout, they 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.

An automated terminal 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. On the other hand, significantly fewer employees will be required for basic container operation and traditional maintenance tasks.

Successful and sustainable automation also requires new key performance indicators for operation planning. These can include

system and subsystem-level performance measurement, tracking of deviations from the normal level of performance, and operation accuracy measuring.

8.2 NEED FOR OPEN DIALOGUE

Conditions, legislation and industry labour norms differ greatly from geography to geography. In many locations, limited availability of skilled personnel – even at competitive salaries – can also be 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.

” Successful change management requires an open dialogue with all relevant parties.

9. 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 more carefully than before. Whether creating a new automated terminal or converting a manual terminal to automated operation, change management is critical.

10. Financial impact

10.1 METRICS

Automation offers clear financial advantages, and the exact numbers (OPEX, CAPEX, 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 expert on its own operations.

Automation projects always revolve around a basic wish list – an idealised implementation that encompasses the swiftest possible deployment, maximum performance improvement, and an integrated





Automatic driving eliminates collisions and accidents in the container yard, decreasing the terminal's insurance premiums.

turnkey solution. Success in practice will depend on skilful optimisation of these and numerous other factors.

10.2 INTEGRATION

A key consideration in an automation project is 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 integrated.

Simply optimising for the cost of individual subsystem components is a shortsighted approach. A delay of just a few weeks on a major automation project can cost of millions of euros in terminal downtime as time to value is extended.

If automation is built with a “bits and pieces” approach, the terminal may save in the very short run, but these savings can be lost already at the deployment stage due to the added complexity of integration and slower ramp-up of productivity. By contrast, a vendor that can offer a completely integrated turnkey solution will be able to provide a system that is not only deployed 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.

10.3 BENEFITS OF EARLY ADAPTATION

Compared with numerous other fields, automation is still a new development for the 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 in competition against automated terminals in the same region. In the worst case, this may even mean the end of business for the terminal.

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.

11. Case study: Patrick container terminal, Brisbane

Patrick is Australia's largest national operator of shipping container terminals, moving more than half of the country's containerised freight. The company has invested more than A\$300 million in its terminal at the Port of Brisbane (which has a quay line of 900 metres) since 2005.

Patrick's journey to automation began in the mid-1990s, when the management team faced the challenge of improving the safety and efficiency of the operation while at the same time containing rising costs. Patrick saw automation as an opportunity to streamline operations and introduce process-line concepts into terminal stevedoring.

Patrick decided to automate existing Kalmar straddle carriers, which made possible a phased transition from manual to automated processes. Patrick's Brisbane terminal now operates 27 Kalmar AutoStrads, and plans to implement 44 AutoStrads and real time control systems automation at the company's Port Botany redevelopment project in Sydney this year.

” Fully automated straddle carriers can operate all day, every day and cut labour costs.

The fully automated container handling system was the first of its kind to be built for unmanned operations. The unmanned Kalmar AutoStrads can operate 24/7 in almost any weather conditions, ensuring smooth flow of cargo and significant cost savings. The transition to automation can be done quickly and at low cost.

Unmanned operation cuts labour costs in the terminal. Machine hours are minimised by employing automatic shutdown, which reduces idle time costs to zero. Additionally, as automated operation does not require night-time lighting, energy savings in a 40-hectare terminal can be significant.

Fully automated straddle carriers can operate all day, every day and cut labour costs. At Patrick a team of only four people is needed to operate a ship-to-shore crane and the yard and stacking area.

Eliminating human error is one of the main benefits of an automated system. The result is a marked improvement in workplace safety. Patrick's AutoStrad terminal has become one of the safest in the world since the introduction of the Kalmar AutoStrad system. ■

AUTHORS

TIMO ALHO

Director, Terminal Automation, Kalmar, is a container terminal automation professional with more than 15 years of experience in research and development, product management and sales in international business environment. His background is in Kalmar straddle carrier and shuttle carrier automation development. He led the project of the onboard automation control system design for automated straddle carriers including software architecture design, software development, testing, commissioning and support in Patrick's AutoStrad terminal project in Brisbane during 2000–2007. Timo Alho is currently responsible for automation sales at Kalmar.

TERO KOKKO

VP, Horizontal Transportation, Kalmar, has long business and technology experience in various industries. He is currently managing the straddle and shuttle carrier business line globally at Kalmar. He holds a Doctor of Technology degree in Automation and Control Technology and has published more than twenty articles in scientific journals related to automation, process control and optimization. He has several patents in the field of automation. In addition to technical education, Dr. Kokko holds a Master's degree in Business Administration.

MICHAEL HICKSON

Horizontal Transportation Automation Product Manager, Kalmar, started his career at Patrick Technology & Systems in Australia in 2002, where he was responsible for design, implementation and commissioning of automation systems at Patrick's Fisherman Island Container Terminal in Brisbane – the world's first AutoStrad terminal. He has led productivity enhancement development programs at Fisherman's Island terminal and played a key role in developing commercial and technical strategies for AutoStrad commercialisation. When Kalmar acquired Patrick's AutoStrad technology in 2012, Michael Hickson became responsible for engineering management and then later product management for AutoStrad technology at Kalmar.

TOMMI PETTERSSON

VP, Automation, Kalmar, has strong experience in software and hardware development, automation project management and project sales as well as related business model development. Before joining Kalmar in May 2014, he worked as CEO in a Finnish industrial investment and development company focusing on demanding automation solutions, and, prior to that, in management positions at Elqotec, a consumer electronics contract manufacturer.

ABOUT THE COMPANY

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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