An automatic choice

The need for automation in container terminals continues with the launch of a new generation of automated guided vehicles (AGVs). Based on equipment from the ro-ro industry the cassette AGV will avoid bottlenecks in container handling operations. Lawrence Henesey, Business Development Manager - R&D from TTS Port Equipment, Sweden, explains.

At the beginning of the 1990s, Europe Container Terminals (ECT) in Rotterdam was the first to adopt an automated transport system for container operation – the automated guided vehicle (AGV). AGVs were (and are still) used for horizontal transport at quayside and automated stacking cranes (ASCs) for vertical transport tasks in the container stacking yard. The original AGVs moved along a pre-determined fixed path such as rails or a guidance system built into the ground. This is the first and oldest automated method in which the path uses wire, tape, or transponders in the ground or pavement. An AGV will sense its location along the path and follow it according to instructions received from a central traffic controller. Usually, a radio message or in some cases infra-red communication is used to pass messages to the AGV from a traffic controller. Unlike fixed path AGVs, their free path counterparts, also used in the port of Rotterdam, are much less restricted in their movements, which allow them to follow a much shorter path from their current position to their destination. In principle, AGVs should be able to drive in any direction. However, the free path AGVs used in the port of Rotterdam must still follow a path. The challenge is in installing, maintaining and changing the physical path based design; hence free-ranging AGV guidance technology is gaining interest. This method uses either inertial navigation technology combined with odometry to control direction speed and positioning, or the more common method is to use a system of mirrors and lasers that are continuously triangulating the vehicles position. This however comes at a price; it requires a more complex built-in navigation system to guide the AGV. However, there are companies such as Danaher Motion that have already provided such technology for nearly 13,000 AGVs. Among the onboard systems required for this are propulsion and steering mechanisms. In addition the AGV requires access to a traffic management system that handles the local path control so as to avoid "dead-lock" and possible collisions and a communication system which allows the AGVs to stay in contact with a central control system.

Cassette AGV

Development in Cassette AGV (C-AGV) technology in terminals is based on the IPSI™ AGV, part of the European Unions' IPSI™ project. These AGVs have been designed to transport containers through the use of an additional buffer in between: cassettes. These cassette AGVs (C-AGVs) have been designed specifically to transport cassettes with containers on them. Each cassette can carry up to two 40ft or four 20ft containers. This allows cranes to continue loading/unloading even when there is no C-AGV available, as long as enough waiting cassettes are present in the buffer area. A decoupling of horizontal and vertical transport processes therefore becomes possible representing a vital key to the system's cargo handling efficiency. The C-AGVs used in this paper are of the newest generation providing a zero-emission all-electric solution. The new vehicles have a load capacity of 61 tonnes, and can carry cassettes with double-stacked 40-foot containers or two 20-foot containers in a single tier. Major improvements to maneuverability are made by incorporating individual electrically driven and steered bogie axles which enable the C-AGVs to be moved in any direction and turn through 360 degrees as seen in Figure 1. This increases the versatility and flexibility of the C-AGV while minimising congestion at the quayside. The C-AGV can be steered conventionally or 'crab' diagonally, or it can move completely transversally. New cassette designs, presented in Figure 2, enable the C-AGV to enter and exit both transversally and longitudinally, i.e. their smaller size allows them to move below the cassette in between its legs at each end, thus eliminating the need for a lengthy line-up operation. The contactless energy transfer technology contains ground-based and vehicle-based segments. The two key components to the ground-based system are the power electronics element and coils, which enables vehicles such as the C-AGV to receive energy both under the quay crane and the yard cranes areas. In addition to the ground-based system, the vehicle-based system employs the same technology and uses super capacitors to store the energy, which is then used by electric wheel motors. With a full load a C-AGV can travel around 600m, depending on its load, after which the capacitor needs to be recharged. The use of capacitors instead of batteries allows for a lighter C-AGV and even though its range on a single load is limited, the capacitor can be – unlike a battery – recharged within 20 seconds. This generation of C-AGVs , as well as being much lighter, is also slightly smaller. This means they are now smaller then the cassettes they carry. The cassettes have therefore been redesigned so that the C-AGVs can now move below them sideways to pick them up whereas the previous generations of C-AGVs had to line up with the cassette and pick them up along their length axis.

Operations at an ACT

Quay crane operations in our yard layout, illustrated in Figure 3 depicts the operations being performed at the back side of the crane. In this new concept all operations are performed either between the gauge of quay crane or at the back sides of the crane, thus decreasing the distance C-AGVs have to travel, while on the other hand, increasing the distance through which the crane has to transport the containers. The space that becomes available below the cranes will be used to store the ship's hatch covers. Additionally this means that the automated area of the yard can be entirely isolated from areas of human activity thus decreasing the risk of unwanted interference. In our yard crane operations layout we have also incorporated a buffer system. Instead of having a buffer with room for four to eight cassettes next to one another, a dual layer approach has been chosen with four 2-deep cassette lanes in which the second row can be reached through two highways leading into the second layer of the buffer, illustrated in Figure 4. The layout in Figure 4 provides eight places reserved for cassettes using the same width with a single layer that six spaces would normally occupy. This system is also easily expandable in depth: by adding an additional layer, the buffer capacity is increased by another four places. The downside of this approach is that for each extra buffer layer, one layer of storage space in the yard would be sacrificed.

C-AGVs operations

There are several "highways" behind the quay crane; five are cassette "highways" on which cassettes wait for containers to be transported to the yard buffer areas and three are highways which can be used by C-AGVs, which are free-ranging and not bound to tracks, so all locations in the cassette lanes are at all times reachable. As these highways are only wide enough for one C-AGV to fit in them, they are single-directional. Points are provided in the highway and cassette lanes where C-AGVs can leave them in order to proceed to the yard area. This will usually be done on locations where there is more room between two successive cranes. As described earlier, the C-AGVs used in this paper are of a new design using an electric propulsion system enabling them to virtually turn around their axis. These C-AGVs are not modeled to be fixed-path instead they are free-ranging. The independently turning wheels also mean they can go from moving forward or backwards to moving sideways by turning the wheels while standing stationary. However the

Figure 1: C-AGV turning 90 degrees in the direction of a loaded cassette

Figure 2: C-AGV travelling under a cassette either from the ends or the sides

reason this has been made possible is due to the electric engines, but they do add an important additional constraint to the traffic management and terminal design; the capacitor fuelling the engines needs to be recharged every 500m to 1000m, depending on the C-AGVs load. For this purpose there are specific recharge points built into the road deck on strategic points such as the hand-over area between C-AGVs and quayside cranes as well as C-AGVs and stacking cranes. When C-AGVs pass above them they can recharge their capacitors to 100% in approximately fifteen seconds, depending on the status of the capacitor before recharging is started.

Traffic management

The Traffic Management System (TMS) controls the flow of traffic throughout the yard area. Most of the TMS is implemented in the C-AGVs themselves. The sensors installed on the C-AGVs will avoid collisions and handle the flow in the free flow areas as well as in the highways and cassette lanes. Moreover, the centralised TMS especially serves to reserve certain cassette places in the buffer areas for specific C-AGVs and avoids deadlocks by granting vehicle priorities. Additionally, the routing of C-AGVs is covered by the centralised TMS, i.e. if C-AGVs are allocated by a job the related instance either organises necessary transport activities or determines the particular traveling path. From the various simulations and studies conducted by companies and industry partners, the number of vehicles needed, the retail costs and fuel or energy consumption have been placed into a spreadsheet calculation to compare the variable cost of moving a container. The spreadsheet is presented in Table 1 and indicates that, when comparing the automated systems that are available in the market, the decoupling of the AGVs and Auto Shuttle Carriers increases the productivity levels of the vehicles. The decoupling of the containers on both the land-side and marine-side is achieved by the C-AGVs and the Auto Shuttle Carriers. The Lift-AGV is able to decouple at only the land-side with the use of steel racks that are placed into the ground. As seen from the table, the simulation results for AGVs shows that more units are required to keep the quay crane from not being idle in order to handle the 100,000 containers. From a cost comparison, the additional units which are less in cost than other automated systems translate into a higher cost for moving a container. The investment costs that are used stem from the purchase price of the vehicle without navigation. Of course the need for a navigation system is essential and can boost the investment cost to over Euros 100,000 depending on the type of navigation system employed. In summary, there have been evolutionary changes in the container terminal industry that are influenced by many factors, such as higher volumes, increasing demands for environmentally friendly equipment and lower costs. Automation is seen by many industry experts as offering possible solutions to their port plans or operational demands. Depending on the terminal operator's objectives and the numerous variables, which are difficult to list and model in a spreadsheet, we suggest that each of the listed automated systems in Table 1 can be used successfully in container terminal operations. The variable cost per container move is just one key performance indicator (KPI) that should be considered among a basket of KPIs.

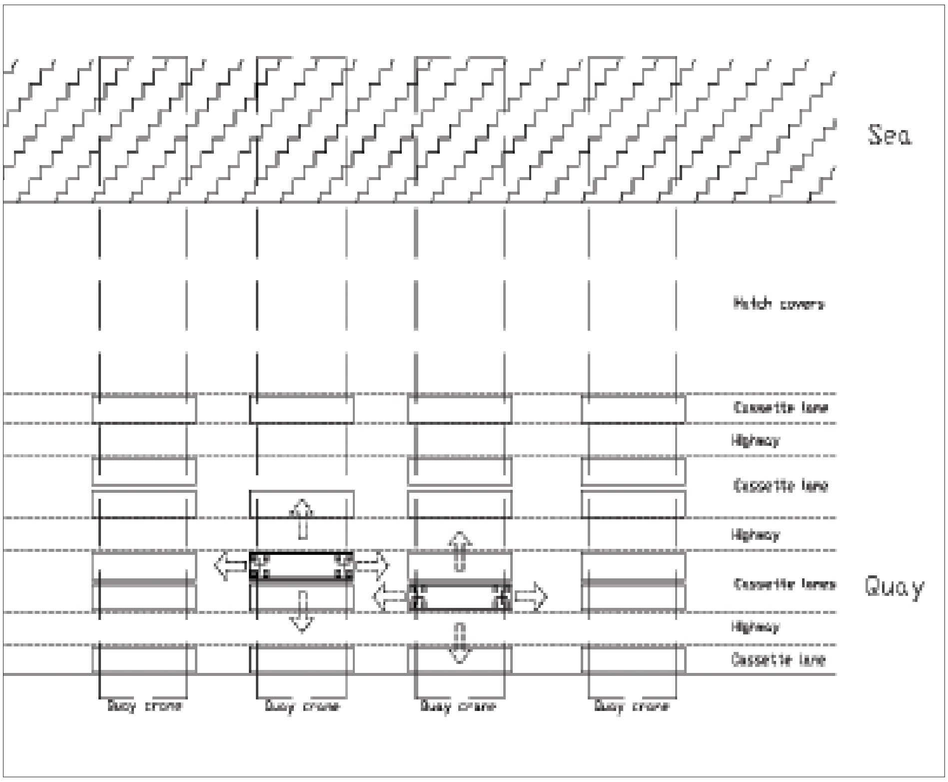

Figure 3: Illustration of C-AGVs driving under the cassettes in either the ends or transversally from the sides of the cassettes

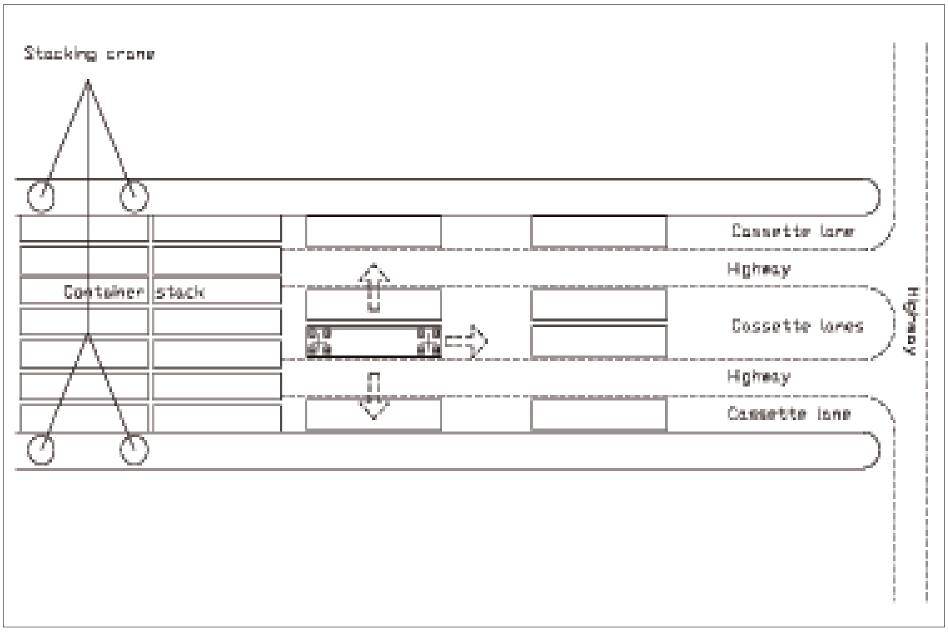

Figure 4: The transfer points at the stacking crane and layout

		AUTOMATED SYSTEMS					
		C-AGV (1 high *un doubled stacked)	Auto SC (1 over 1)	L-AGV (1 over 1)	AGV	Z-AGV	C-AGV (2 high doubled stacked)
Assumptions		(investment)	(investment)	(investment)	(investment)	(investment)	(investment)
QC cranes							
Production QC	mv/year	100 000	100 000	100 000	100 000	100 000	100 000
Gross productivity QC	mv/h	35	35	35	35	35	35
Gross working hours QC	per year	2,857	2,857	2,857	2,857	2,857	2,857
Vehicles							
Operational vehicles		3,5	3,0	5,0	7,0	5,0	5,0
Additional vehicles	maintenance & repair	0,5	0,5	0,5	0,5	0,5	0,5
Total number vehicles / QC		4,0	3,5	5,5	7,5	5,5	5,5
Total number of Cassettes/Bomb Carts (trailers)		12,0	0	0,0	0,0	10,5	10,5
Gross working hours vehicles	per year	10000	8571	14286	20000	8571	8571
Investment cost	per vehicle	€ 450 000	€ 900 000	€ 550 000	€ 360 000	€ 300 000	€ 450 000
Investment cost for Transfer	per unit						
Investment cost Cassettes/Bomb Carts (trailers)		€ 10 000		€ 0		€ 10 000	€ 10 000
Gross Investment for Vehicle + Equipage		€ 1 920 000	€ 3 150 000	€ 3 025 000	€ 2 700 000	€ 1 855 000	€ 1 680 000
Depreciation	number of years	10	12	10	10	10	10
Maintenance Cost	% of investment	5%	8%	6%	5%	5%	5%
Interest	% of investment	6%	6%	6%	6%	6%	6%
Fuel consumption	litre / hour	10	19	20	20	5	19
Total fuel cost	€1 / litre	€ 190 000	€ 162 857	€ 285 714	€ 400 000	€ 42 857	€ 162 857
Infrastructure Costs							
Infrastructure costs for one unit (e.g. Bank or Battery Transfer Point)			€ 0	€ 0	€ 18 000	€ 0	€ 4 500
Total Number of Infrastructure Units				8		32	
Total Infrastructure Cost for Infrastructure Units		€ 0	€ 0	€ 144 000	€ 0	€ 144 000	€ 0
Infrastructure Costs divided per Vehicle		€ 0	€ 0	€ 26 182	€ 0	€ [illegible]	€ 0
Costs vehicles							
Depreciation	vehicle investment	€ 192 000	€ 262 500	€ 302 500	€ 270 000	€ 185 500	€ 168 000
Var cost vehicle		€ 401 200	€ 603 857	€ 674 896	€ 697 000	€ 288 050	€ 347 657
Totals							
Var costs total		€ 593 200	€ 866 357	€ 977 396	€ 967 000	€ 473 550	€ 515 657
Var costs / ts		€ 5,93	€ 8,66	€ 9,77	€ 9,67	€ 4,74	€ 5,16

Table 1: Cost comparison of Quay Crane (marine-side) transportation systems

Automatic response

Sweden-based Kollmorgen (former Danaher Motion) provides AGV control technology to a wide range of market segments. With an increasing amount of goods coming into ports and then being sent to the end-customers via distribution centres, the company recognised a need for automated transportation in parts of this logistics chain. Via TTS Port Equipment they provide the ports market with AGV technology. Their control technology is used in many market segments and is the same for all types of applications. Typical applications are material handling within various manufacturing plants (paper & printing, brewery, steel, electronics, automotive, ceramics & tiles, etc). They are currently focusing on AGV technology for the logistics and distribution sector. In this segment the AGVs often operate together with manual vehicles and walking personnel (in the same area). This requires additional safety solutions. For distribution centres they have developed a concept called Pick-n-Go, where the warehouse trucks are automated for order-picking and pallet transportation.

Gottwald continues to innovate

With regards to their Automated Guided Vehicles (AGVs), Germany-based Gottwald Port Technology, has made technological progress in recent years in order to extend their technological leadership in this field. The automated equipment business including hardware and software is Gottwald's second 'business column' and the company is currently working on some AGV projects but are bound by confidentially. In 2008, Gottwald introduced the Lift AGV based on the conventional AGV of which hundreds are operating very reliably several thousand hours a year. The Lift AGV was developed in order to provide better productivity for operators and this was achieved by decoupling the container transport and container stacking processes in the Automated Stacking Cranes (ACS) inter-change zone. To further enhance productivity of the AGVs, Gottwald focused its R&D activities on energy-efficient and green technologies in order to bring new drive systems to market. One of the outcomes was the Battery AGV which was developed together with Gottwald's customer HHLA in Hamburg, Germany. Extensive testing of the Battery AGV took place at the HHLA Container Terminal Altenwerder (CTA) under real terminal conditions. The results were very promising with the AGV operating for 12 hours and with a recharge time of 6 hours there was only the need to change 1 battery per 2 AGVs. Research also showed that the efficiency of the battery drive train was much better than the diesel generator efficiency, even including charging of batteries. Gottwald also intends to develop an automated battery change station and a battery charging management system for integration in the fleet management system. However, it was not only the efficiency of the Battery AGV that was so remarkable; another development was the significant reduction in the noise level. "While the conventional diesel-electric AGV generates noise typically associated with diesel engines, the Battery AGV hums more like an electric tram," said Armin Wieschemann, Head of System Development & Consulting and Project Leader Battery AGV. Another bonus was that the navigation system of the diesel-electric AGV can be used without modifications for the Battery AGV reducing costs even further. Gottwald is also undertaking additional efforts in order to develop green drive technologies.