final report

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Mobile Robot AGV Stage 1

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Abstract

The tasks of Palletising, De-palletising and Container loading are very labour intensive, requiring the lifting of heavy boxes (up to 30kg) with high OH&S risks. All the plants visited as part of Milestone 1 of this project expressed a desire eliminate as much labour as possible in these areas while maintaining or improving the time taken to perform the tasks. With these points in mind, MAR concepted, designed, built and demonstrated the use of a robot mounted on an AGV in performing the tasks of:

- Palletising
- De-Palletising
- Container Loading
- Mixed Pallet Sortation
- Mixed Pallet Order Picking

The potential benefits of automating these functions include:

- Reduction in labour
- Improved OH&S – reduced injuries and accidents
- Improved rates – loading times could be quicker, improving turnaround time & carton cooling efficiencies
- Improved efficiencies – efficient carton loading consistent and repeatable operations
- Traceability – controlled operations each carton scanned and catalogued (time & location), eliminating potential ‘lost product’
- Quality – reduced manual handling promotes better quality end product (reduce carton damage)

Executive Summary

The tasks of Palletising, De-palletising and Container loading are very labour intensive, requiring the lifting of heavy boxes (up to 30kg) with high OH&S risks. All the plants visited as part of Milestone 1 of this project expressed a desire eliminate as much labour as possible in these areas while maintaining or improving the time taken to perform the tasks. In addition two of the plants expressed interest in the use of a mobile robot after hours where, traditionally, mixed pallets of low volume product that had been manually palletised during the day and stored are manually resorted. Again this is currently a labour intensive task with the associated OH&S risks. The thinking is that the pallets of mixed product could be laid out, along with an array of empty pallets. The Mobile Robot could then be set the task of sorting the pallets of mixed product onto pallets of like product with minimum operator intervention. Alternatively the mobile robot could be used for order picking in a similar setup where pallets of product would be laid out and the mobile robot set the task of picking a mixed pallet from pallets of known product.

The potential benefits of automating the above functions include:

- Reduction in labour
- Improved OH&S – reduced injuries and accidents
- Improved rates – loading times could be quicker, improving turnaround time & carton cooling efficiencies
- Improved efficiencies – efficient carton loading consistent and repeatable operations
- Traceability – controlled operations each carton scanned and catalogued (time & location), eliminating potential ‘lost product’
- Quality – reduced manual handling promotes better quality end product (reduce carton damage)

With these goals in mind, MAR concepted, designed, built and successfully demonstrated the use of a robot mounted on an AGV to perform the tasks of:

- Palletising
- De-Palletising
- Container Loading
- Mixed Pallet Sortation
- Mixed Pallet Order Picking

Contents

1 Background

MAR has focussed on developing an automation strategy for a number of years developing plans and identifying possible automation opportunities for red meat processing.

Areas within red meat processing such as materials handling (e.g. cartons) are prone to product damage, product loss, traceability issues, OH&S issues and production inefficiencies. Automation in these areas will be of great benefit to the industry.

MAR has a concept to develop an automated solution for container loading utilising automated guided vehicles “AGV” and robotics this project will provide valuable learning as a proof of concept for this automation and others.

Automated Container Loading concept in principle for reference:

- Cartons are conveyed via traversable conveyor fixed to an AGV system
- All barcodes on cartons will be scanned for tractability and confirmation
- All cartons will be 3D profiled to detect carton bulge
- Cartons will be unloaded from conveyor via robot mounted on AGV and stacked in container in required stacking pattern
- AGV, Robot and conveyor traverses in and out of container as required
- Cycle repeats until container is full.

MAR has extensive experience with carton and materials handing handling utilising robotics and AGV systems. Other technologies developed by MAR for vehicle mounted robotics dealing with variable conditions will prove invaluable.

2 Project Objectives

The project will provide the following outcomes:

- Mobile Robot using AGV system designed and built at MAR
- POC trials at MAR to establish capabilities for materials handling concepts (container loading, palletising and de-palletising)
- Demonstrate working concepts to industry
- Provision of concept proposals for working solutions
- Detailed report to outline findings and possible uses for red meat processing.

3 Methodology

The objectives will be achieved by completing the following milestones:

Milestone 1 - Scope study & preparation. Milestone report approved by MLA.

Milestone 2 - System design. Milestone report approved by MLA.

Milestone 3 - Purchase components and manufacture POC system. Milestone report approved by MLA.

Milestone 4 - Perform POC trials at MAR, demonstrate POC to MLA. Complete CBA (via adoption project) milestone report including CBA approved by MLA.

Milestone 5 - Demonstrate concept to industry and MLA via industry workshop.

Milestone 6 - Final report approved by MLA.

4 Results and Discussion

4.1 Scope Study and Preparation

With a view to obtaining processor buy in and possible new ideas for applications for a Mobile Robot on an AGV, MAR in conjunction with MLA undertook visits to 3 processors. The plants visited were Teys Bros, JBS Beef City and Kilcoy Pastoral Company.
During these visits the discussion centred around where a Mobile Robot AGV could be used to automate tasks in the carton handling and load out areas. Specifically in the areas of:

- Palletising
- De-Palletising
- Mixed Pallet Sortation
- Mixed Pallet Order Picking
- Container Loading

The areas where these activities take place are commonly restricted in space and require a high degree of manual labour to sort the different products onto specific pallets which are then stored in racking until required. Discussion with the processors highlighted number of points and issues that would need to be considered during the development and design of any automated system in this carton handling area. The items raised included:

- Frozen carton bulge making the cartons difficult to handle and stack
- Weight of the cartons (up to 30kg)
- Difficulty in retaining employees due to the strenuous nature of the tasks
- Is there an advantage in replacing push pull loading of containers with automation?
- Losing product due to lack of ability to track product when handled manually
- Difficulty in sorting product due to lack of space and the requirement to do this manually out of hours
- Different stacking patterns based on product type and market/final destination
- Current carton dimensions are fixed based on existing machinery
- Multiple loading docks – does each loading dock need a dedicated container loading system?
- Port marking and barcode scanning, currently it is difficult to reliably track cartons.
- Currently it is often difficult to locate required pallets in storage area, costing time, an automated system that could track pallet location would be of benefit.

- Most plants have 3 different carton sizes and a mixture of Chilled, Blast and Plate frozen product.

- Different methods of dunnage use in stacking containers

- Different methods of stacking containers depending on size of container, ie 20ft containers usually stacked to the full height, while 40 ft containers are not due to weight restrictions.

- Sortation of domestic product

The tasks of Palletising, De-palletising and Container loading are very labour intensive tasks requiring the lifting of heavy boxes (up to 30kg) with high OH&S risks. The plants visited all expressed a desire to eliminate as much labour as possible in these areas while maintaining or improving the time taken to perform the tasks. Using container loading as an example, the potential benefits of automating this function would include:

- Labour – estimate replacing 3 operator(s) per working shift
- OH&S – reduced injuries and accidents
- Rates – container loading times could be quicker, improving loading dock turnaround time & carton cooling efficiencies
- Improved efficiencies – efficient carton loading consistent and repeatable operations
- Traceability – controlled operations each carton scanned and catalogued (time & location), eliminating potential 'lost product'
- Quality – reduced manual handling promotes better quality end product (reduce carton damage)
- Automation – provides ideal platform for carton automation (Chiller, Freezers, Sortation, Palletising)

As well as the use of a Robotic AGV for Palletising, De Palletising and Container loading interest was expressed at both Beef City and Kilcoy that a potential use of a mobile robot would be after hours where, traditionally, mixed pallets of low volume product that had been manually palletised during the day and stored are manually resorted. Again this is currently a labour intensive task with the associated OH&S risks. The thinking is that the pallets of mixed product could be laid out, along with an array of empty pallets. The Mobile Robot could then be set the task of sorting the pallets of mixed product onto pallets of like product with minimum operator intervention. Alternatively the mobile robot could be used for order picking in a similar setup where pallets of product would be laid out and the mobile robot set the task of picking a mixed pallet from pallets of known product. Similar to the above the benefits of automating these tasks include:

- Reduction in labour – the robot could be set the task of sorting or order picking with minimal operator intervention.
- Improved OH&S – reduced injuries and accidents
- Improved rates – pallet loading times could be quicker, improving turnaround time & carton cooling efficiencies
- Improved efficiencies – efficient carton loading consistent and repeatable operations
- Traceability – controlled operations each carton scanned and catalogued (time & location), eliminating potential 'lost product'

- Quality – reduced manual handling promotes better quality end product (reduce carton damage)

With these points in mind and taking into consideration the items raised by the processors earlier in this report, MAR proposed the design of a Mobile Robot/AGV demonstration to include the following materials handling tasks as a Proof of Concept:

- Palletising
- De-Palletising
- Mixed Pallet Sortation
- Mixed Pallet Order Picking
- Container Loading

4.2 System Design

The POC system consisted of the following major items to enable the desired functions to be demonstrated:

- An Automatically Guided Vehicle (AGV)
- Robot
- Mounting platform for Robot and Robot controller
- Gripper
- Carton in feed conveyor
- Pallet conveyor
- Carton out feed conveyor
- PLC for control of the overall system
- VSD's for conveyor control
- Simulated container to enable container loading to be demonstrated
- Cartons and pallets

4.2.1 AGV

The AGV was leased from NDC Automation. The style of AGV that is available for lease is a fork lift style as shown below.

Fig 1. The NDC supplied AGV used for POC trials

The use of this forklift style AGV required the design and build of a platform to mount the robot and robot controller onto. In reality a platform style AGV would be utilised similar to the ones shown below. This would eliminate the need for a platform with the robot and controller being directly fixed to the top of the AGV.

Fig 2. Platform style AGV's

4.2.2 Robot and Controller support Platform

The images below show the platform that was designed to support the robot and controller. The structure was required to support a total weight of approximately 600kg in a stable manner to allow the robot to operate at a realistic speed. Consideration was also made to allow room on the platform to stack cartons in order to simulate order picking.

4.2.3 Robot

The robot used was an ABB IRB 4600 with IRC 5 controller. It will had a pay load of 60kg and a reach of 2.05m. This would be the typical sized robot for this application, satisfying the maximum weight of the boxes (30Kg) and the maximum likely reach requirements.

Fig 3. ABB IRB 4600 Robot and IRC5 Controller

4.2.4 Gripper

The gripper used for the demonstration was the pneumatic gripper shown in the image below. For the purposes of the demonstration this was deemed suitable, the cartons to be used will be empty and hence have no weight in them. In reality a gripper would need to be designed suitable for lifting 30kg cartons. In the demonstration the gripper 'gripped' the carton on the side of the carton which allowed for suitable demonstration of the container loading process.

Fig 4. Pneumatic Gripper to be used for demonstration

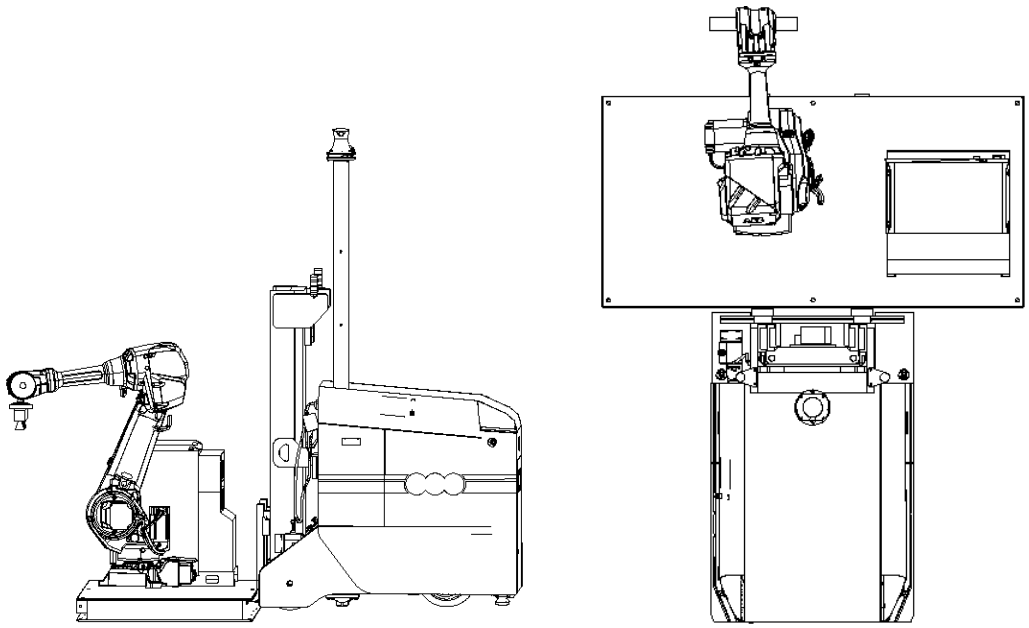
4.2.5 Camera

A Microsoft Kinect 3D camera was used during the demonstration of container loading to detect the height of the stack of cartons and ensure each row is placed correctly.

Fig 5. Microsoft Kinect 3D Camera to be used in the demonstration

4.2.6 Combined AGV, Robot, Platform and Gripper

Following the decision on which AGV, Robot, gripper and camera were to be used and the design of the platform completed the following design drawings of the combined AGV, Robot, gripper and platform were assembled to allow the system to be modelled and the layout for the demonstration in MAR's work shop to be decided upon.



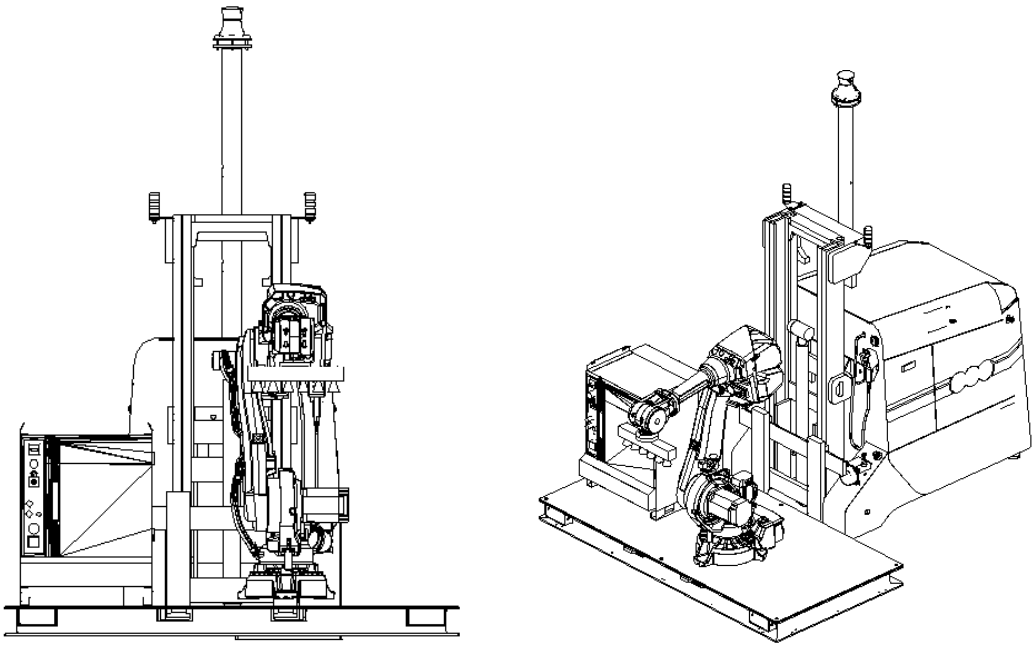


Fig 6. Combined AGV, Robot and platform design

4.2.7 System Layout

With the combined AGV/Robot modelled, the layouts were developed to suit the tasks to be demonstrated,

- Palletising
- De-Palletising
- Container Loading
- Mixed Pallet Sortation
- Mixed Pallet Order Picking

and the available space in MAR's factory at Silverwater. The following conveyors were to be utilised

- Infeed carton conveyor
- Pallet conveyor
- Out feed carton conveyor

and along with a frame used to simulate a container and the combined AGV/Robot unit form the layouts shown below.

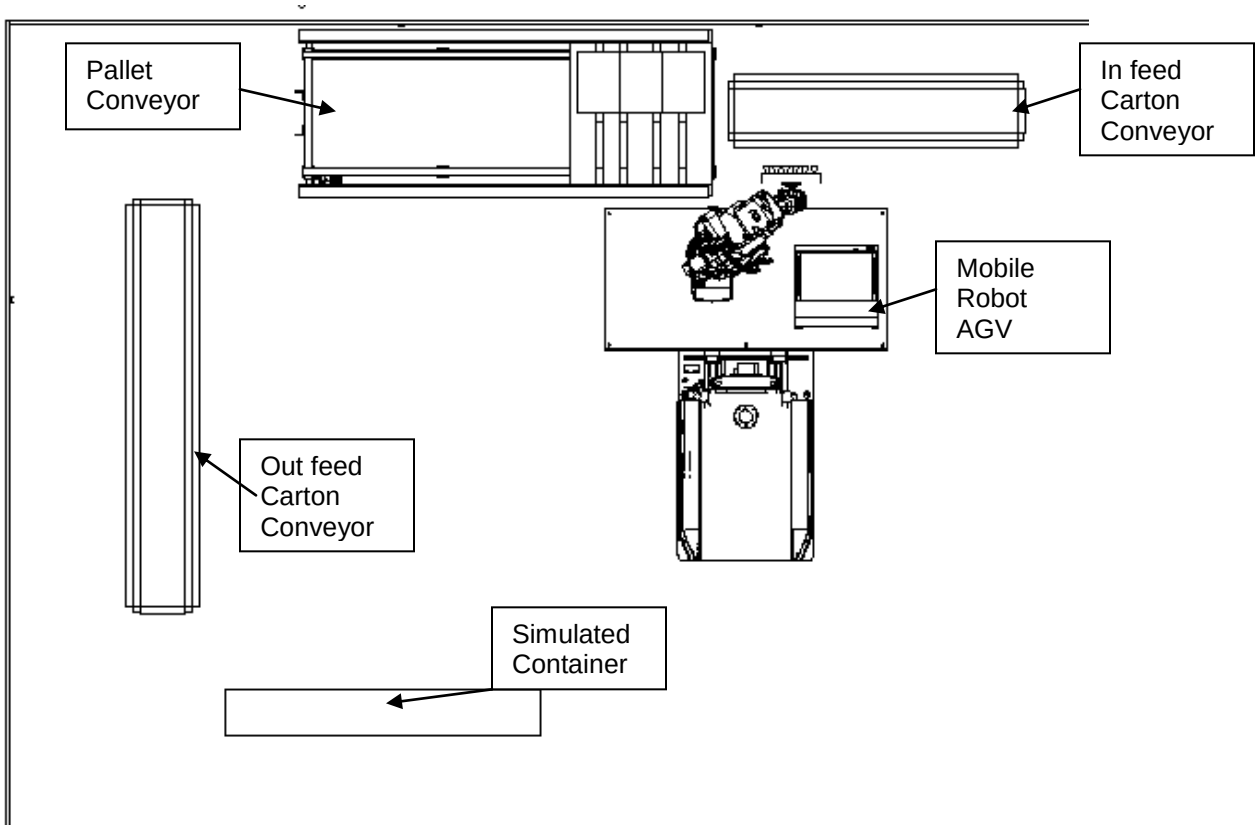


Fig 7. Robotic/AGV layout for demonstration of Palletising, De-Palletising and Container loading

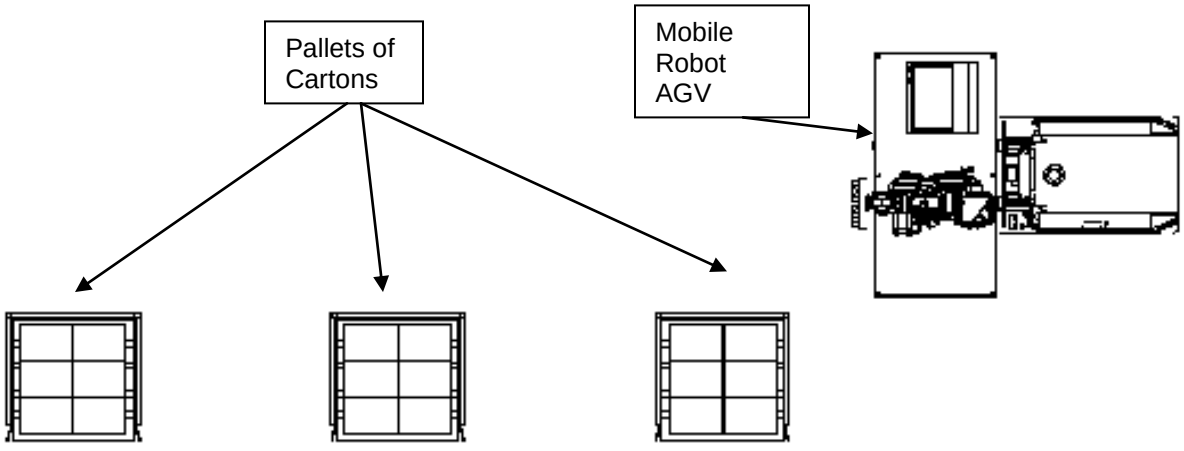


Fig 8. Robotic/AGV layout for demonstration of Mixed Pallet Sortation and Order picking.

4.2.8 System Simulation

From these layouts, simulations of the demonstration were developed. The images below are screen shots of the simulations and confirm the ability of the robot and AGV to perform the required task in the available space.

1) The first sequence of images shows the AGV in three different positions demonstrating palletising, de-palletising and container loading.

a) In the first position it will demonstrate the palletising of cartons from the in feed conveyor on to a pallet located on the pallet conveyer. In reality palletising is better served by a dedicated robot system, however a mobile system could be used in case of break downs where it could be positioned in dedicated locations to get product onto pallets and keep production moving.

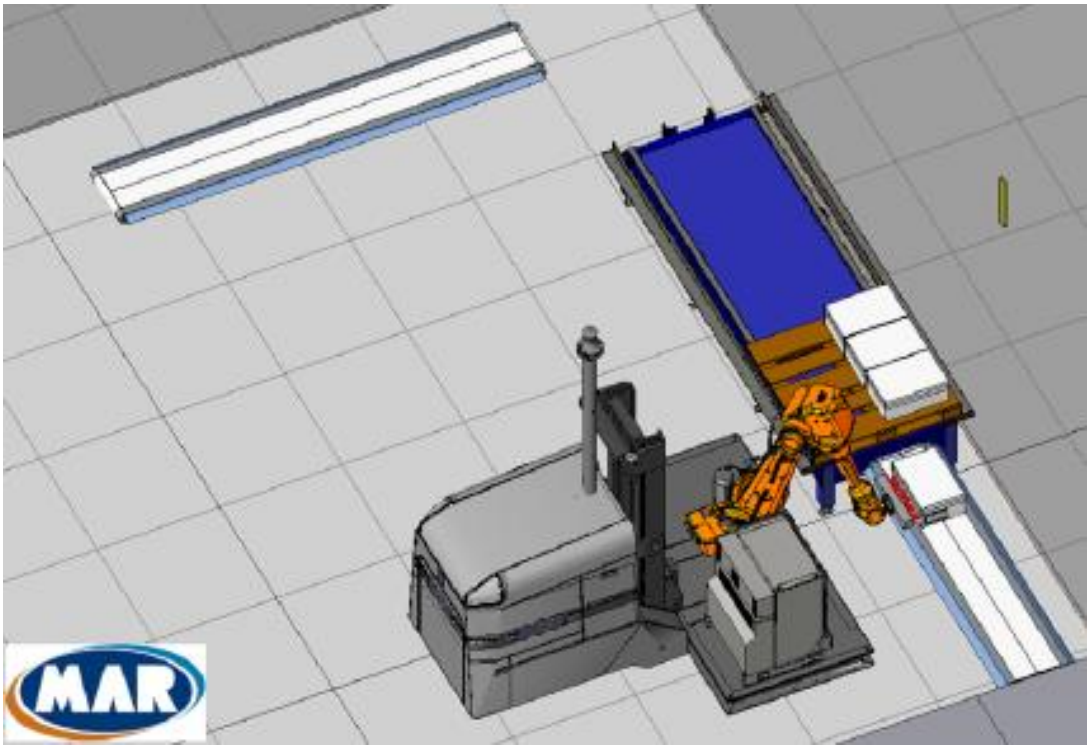


Fig 9. Robotic/AGV in Palletising position.

b) The second image shows the system in a position to de-palletise the cartons from the pallet conveyor to the out feed conveyor. Potential uses for de-palletising include:

- feeding a container loading system, the AGV could move from container to container with the loading system and feed the system cartons via its in feed conveyor.
- Utilising a dedicated palletising system that palletises high volume product during the day, to palletise low volume product during a night shift. Ie during the day the low volume product is manually stacked onto pallets which are stored until required. During the night shift these pallets are positioned so that the AGV can de palletise onto a conveyor that feeds the dedicated system.

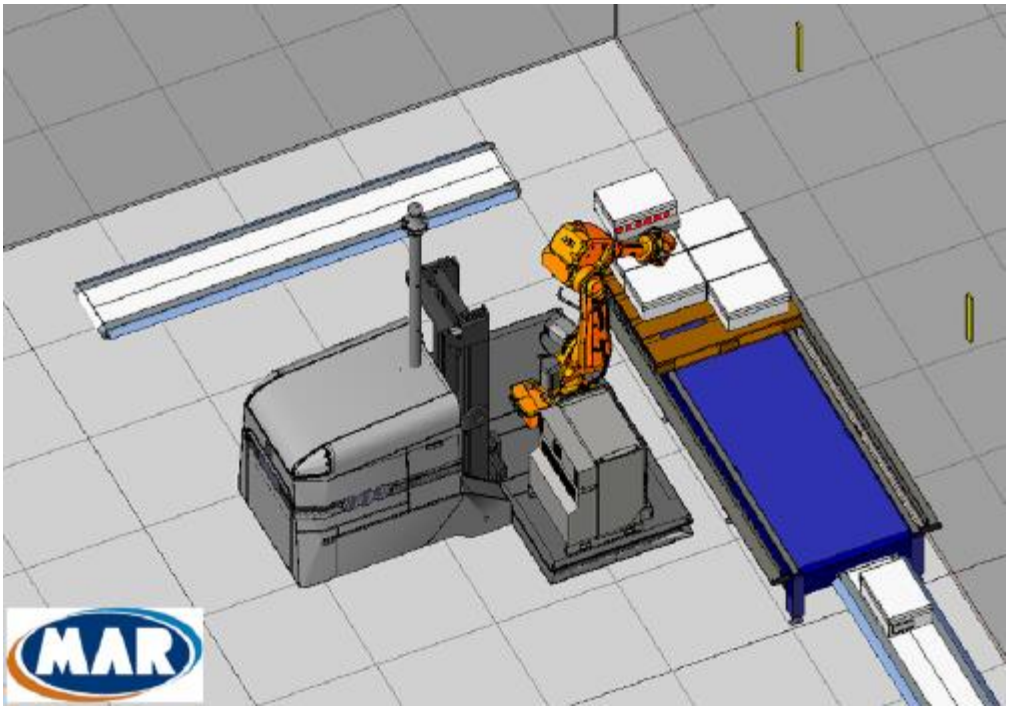


Fig 10. Robotic/AGV in De-Palletising position.

c) The third position it will demonstrate container loading from the out feed conveyor to a simulated container. MAR has a concept to develop an automated solution for container loading utilising AGV's and robotics. In principle the container loading system would operate as follows:

- Cartons are conveyed via traversable conveyor fixed to the AGV system
- All barcodes on cartons will be scanned for tractability and confirmation
- All cartons will be 3D profiled to detect carton bulge

- Cartons will be unloaded from conveyor via robot mounted on AGV and stacked in container in required stacking pattern
- AGV, Robot and conveyor traverses in and out of container as required
- Cycle repeats until container is full

For the demonstration the cartons will be picked up by the pneumatic gripper from the side and loaded into the mock container. The box will then be 3D scanned to determine carton height and potential bulge in the box so that the next carton to be placed on top can loaded accurately.

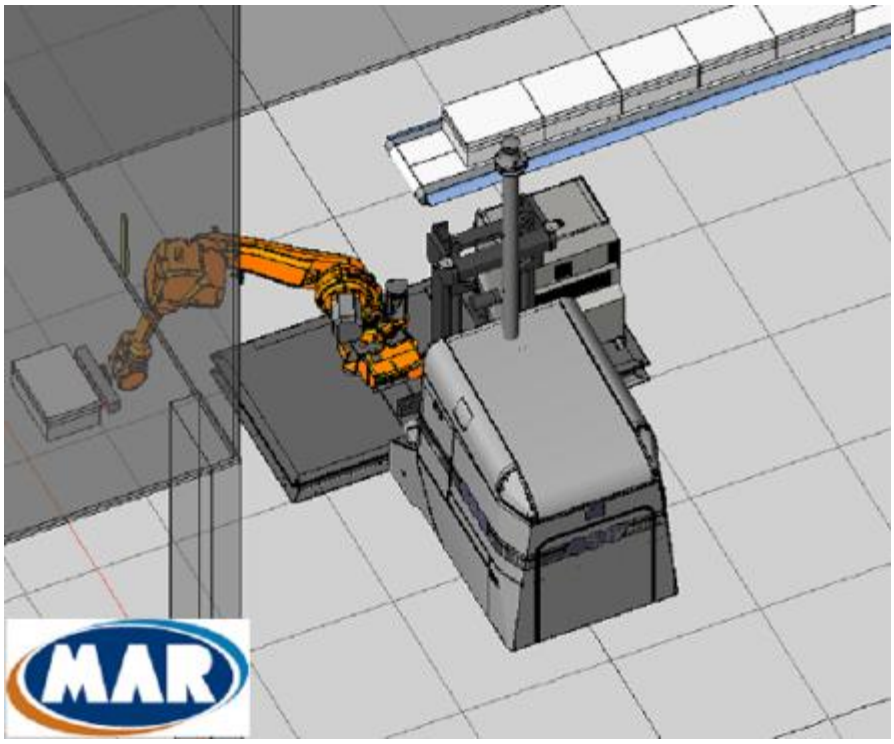


Fig 11. Robotic/AGV in Container Loading position.

The image below shows the reflective tape mounted on the surrounding walls and the mast mounted laser sensor used by the AGV to navigate its way around the work shop. This is one method used other methods include:

- Magnetic Spot navigation – this is often used in conjunction with laser navigation to allow vehicles to operate in extremely confined sections of a warehouse

- Vision navigation – this uses a live video stream from cameras mounted on the vehicle to determine its location.

- Range Navigation – this uses a laser safety sensor to navigate by seeing walls and other obstacles. This is technology is specially designed to operate in narrow corridors.

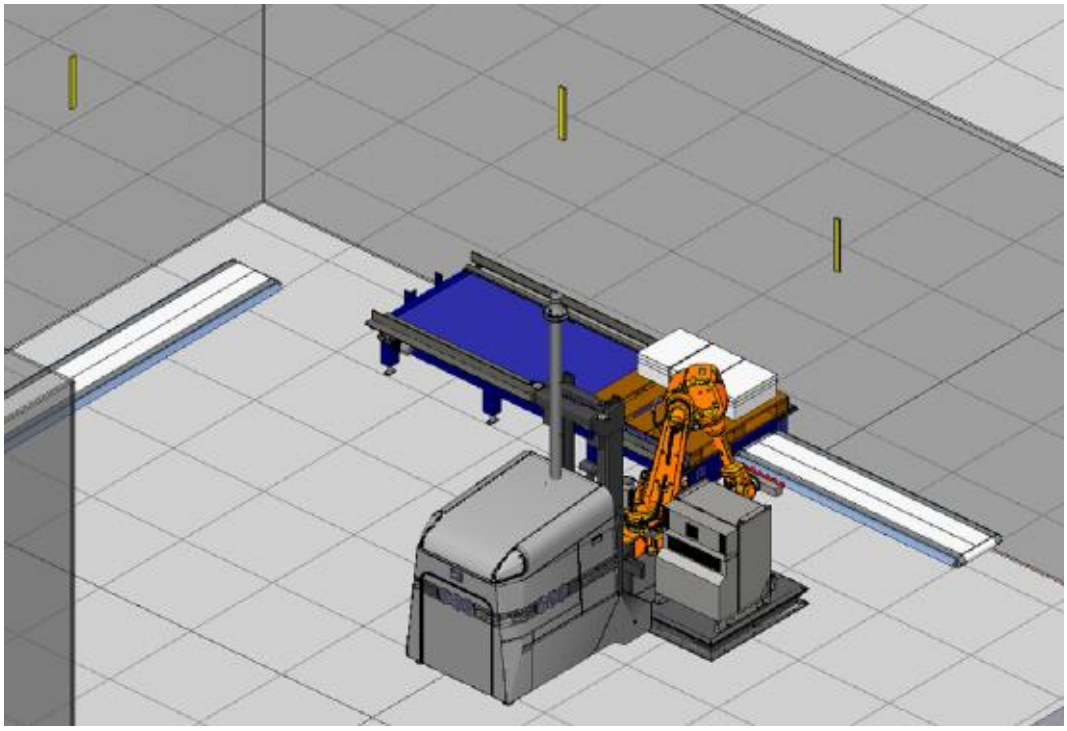


Fig 12. Robotic/AGV positioned showing reflective tape, which along with mast mounted sensor is used by the AGV to verify its location.

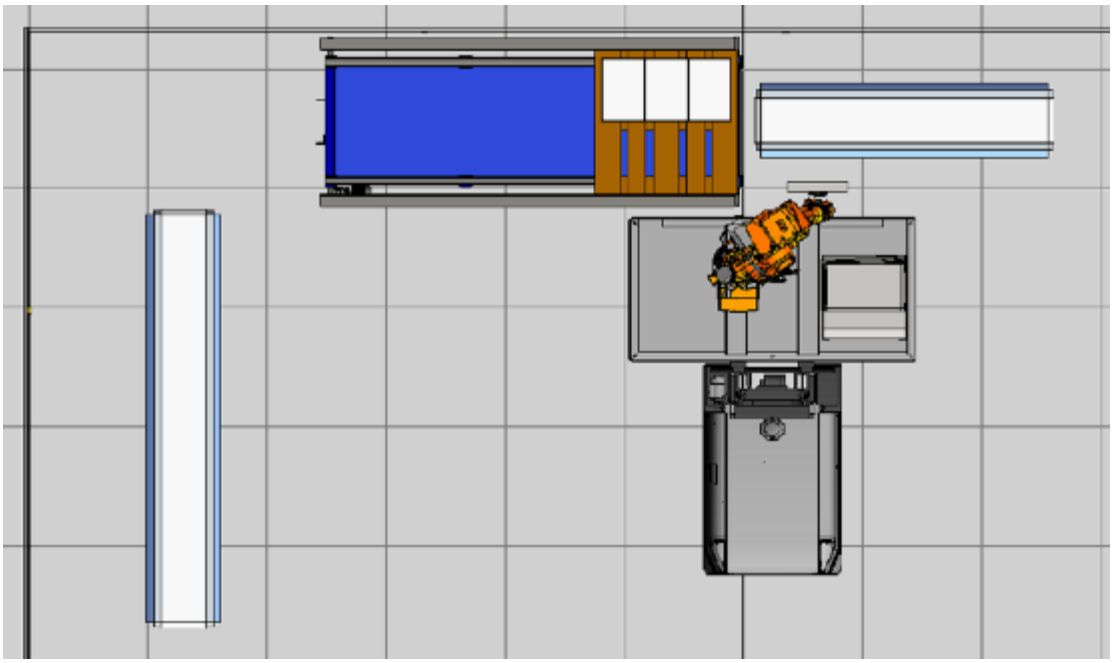


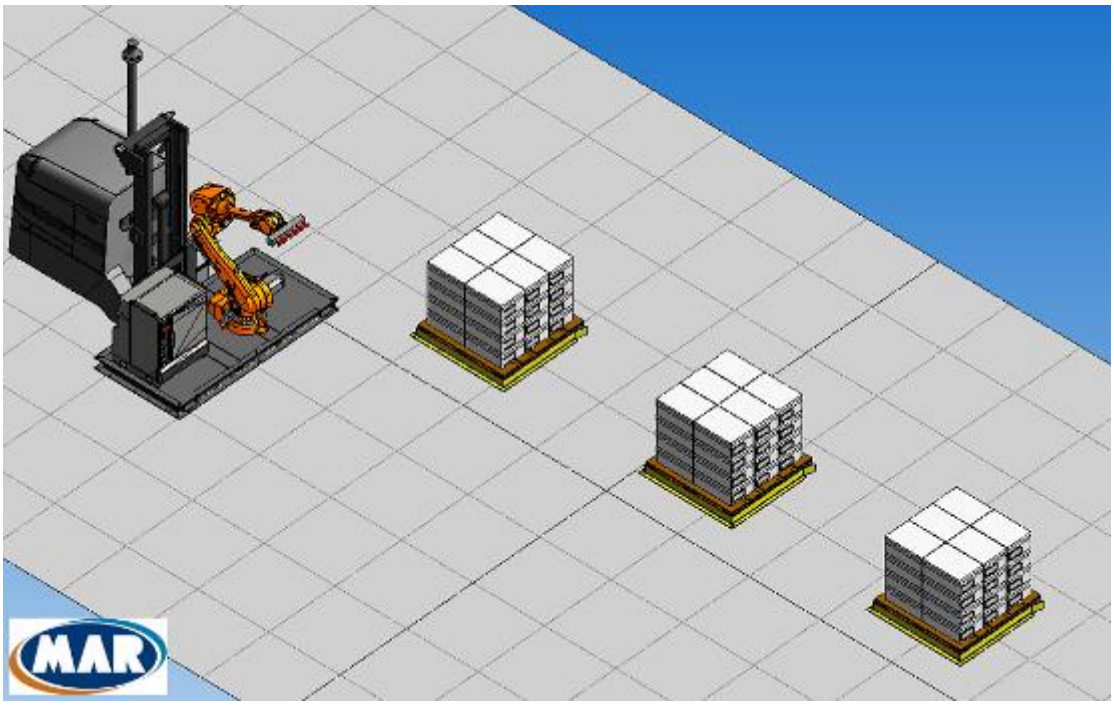
Fig 13. Plan view of palletising, de-palletising, container loading setup

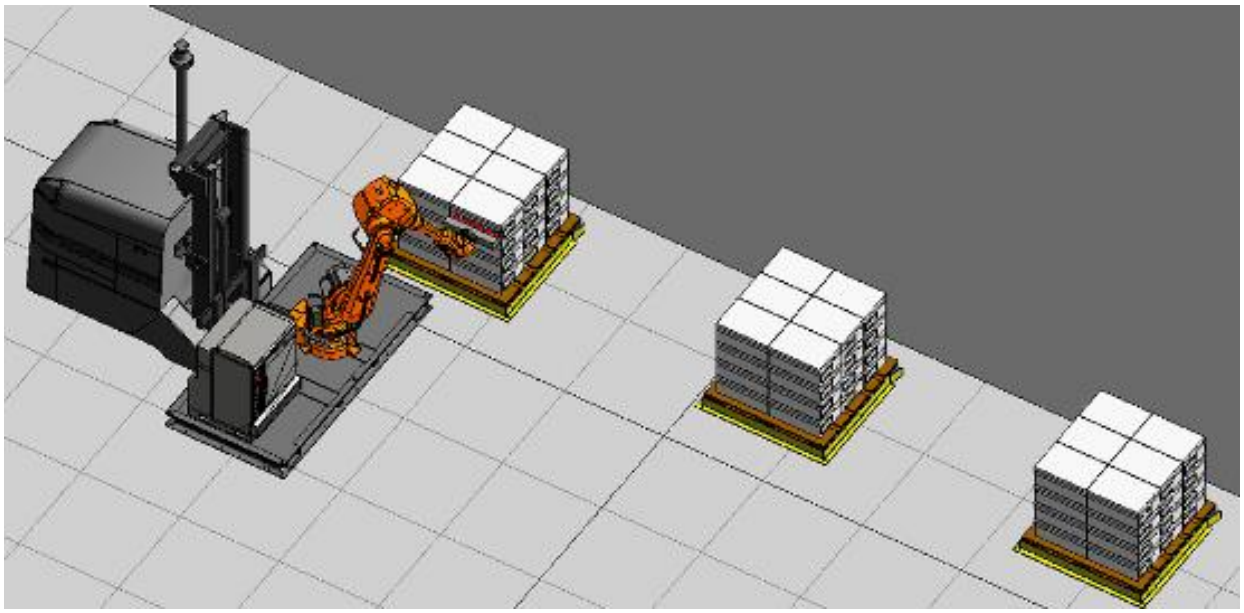
2) The second sequence of images shows the AGV demonstrating mixed order picking.

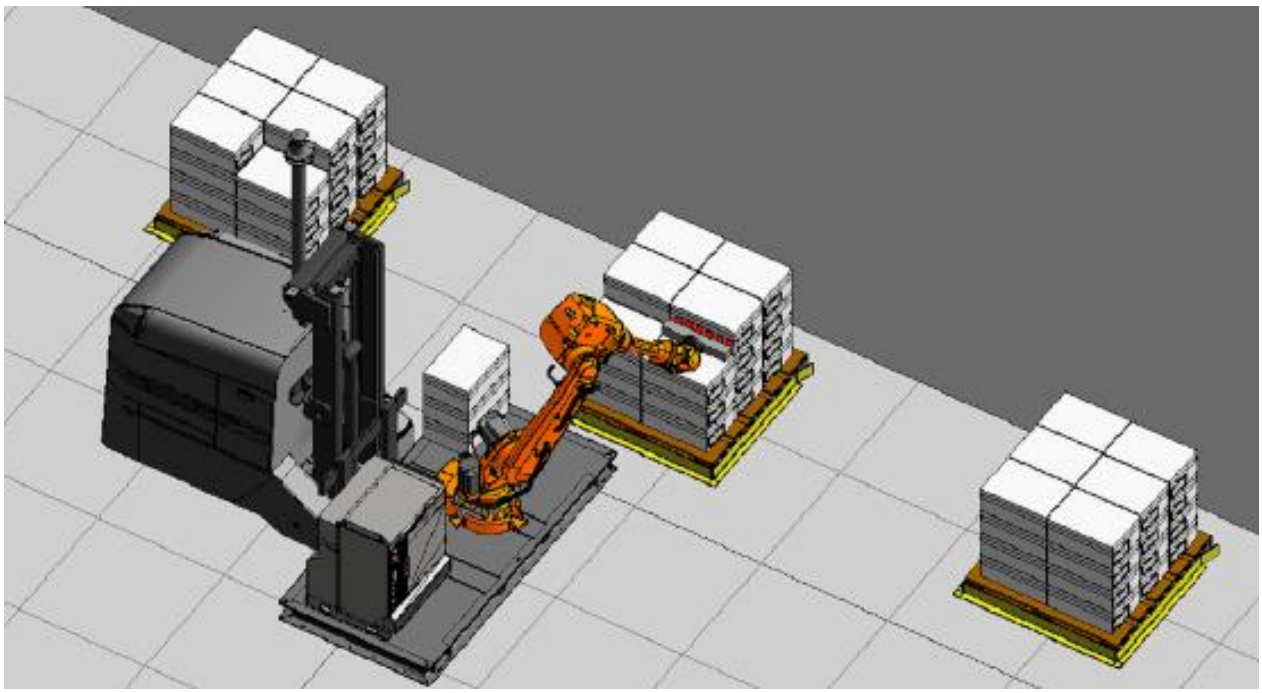
   a) For mixed order picking:

   - The AGV would have a dedicated order to pick and pallets of known product would be laid out in the available space.
   - The AGV would approach each pallet and 3D scan it to determine the height of the cartons present
   - The cartons would then be bar code scanned to confirm product type.
   - The required number of cartons from that pallet would then be picked and placed onto a pallet on the AGV
   - The AGV would then move onto the next pallet and repeat the process until the order was filled.
   - Once the pallet was full/order filled the AGV would deposit the pallet into a dedicated area for shipping.

   In the demonstration the robot will be loading the cartons onto the fixed platform, in reality it is envisaged that there would be a pallet that could be picked up by the AGV, filled and then deposited as described above.







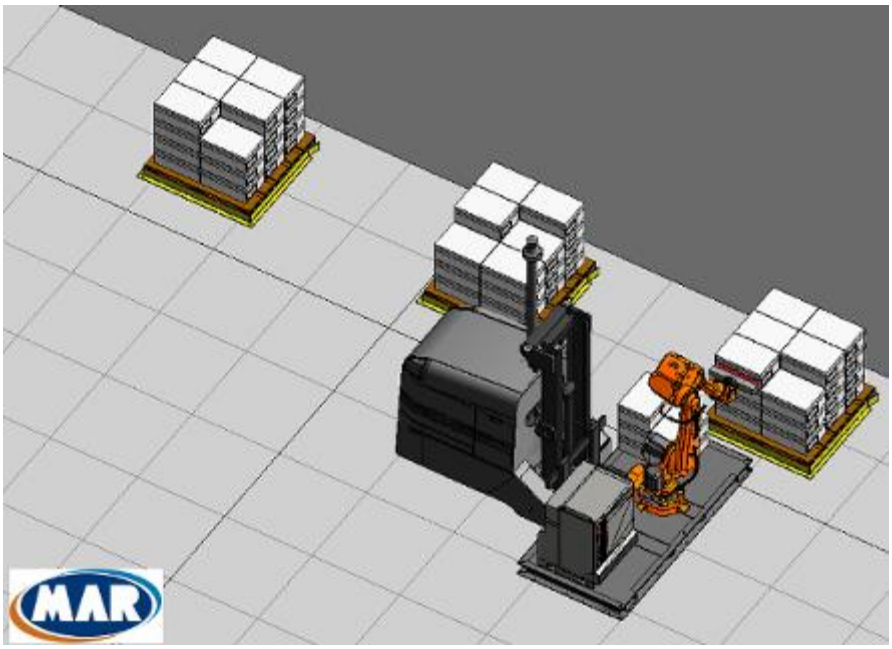


Fig 14. Images demonstrating mixed order picking

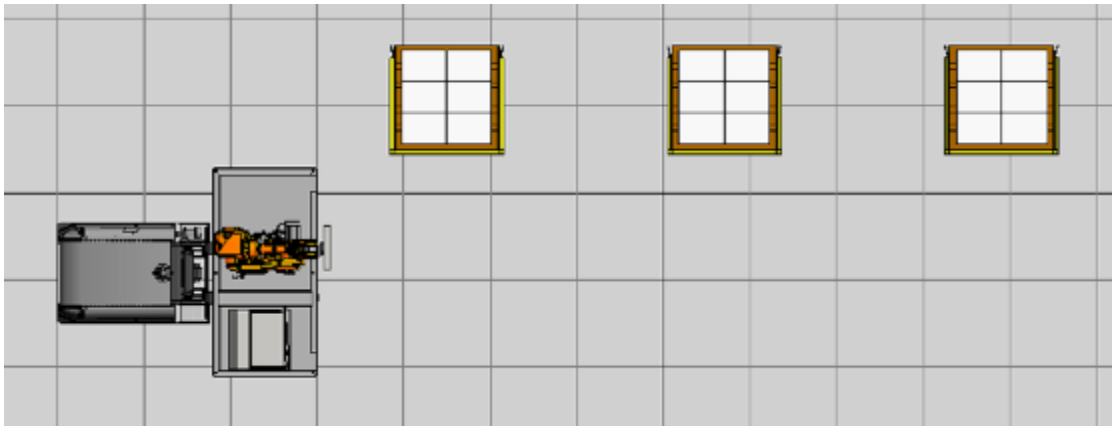


Fig 15. Plan view of mixed pallet sortation and order picking

b) A similar system could also be used to sort product:

- This would involve full pallets of mixed product being laid out on the floor, along with an array of empty pallets.
- The AGV would approach each pallet and 3D scan it to determine the height of the cartons present
- The cartons would then be bar code scanned to confirm product type.
- The cartons would then be individually picked and taken to an empty pallet where like products would be palletised.

It is envisaged that the process of order picking and product sortation would take place out of hours where the floor space normally used for other purposes during the day could be filled with pallets. The AGV/Robot could then perform these duties with a minimum of operator supervision/intervention.

4.3 System Build and Demonstration

The system described above was built and the Demonstration of the system performing these tasks was conducted at MAR's workshops in Silverwater NSW on the 23rd of October 2012. The demonstration was attended by:

Dean Goode – Kilcoy Pastoral Company

John Coughlan – Teys Australia

John Hart – John Dee

Darryl Heidke – Meat and Livestock Australia

A video of this demonstration has been burnt to CD and sent to Darryl Heidke of MLA

5 Success in Achieving Objectives

This project has successfully concepted, designed, built and demonstrated the use of a robot mounted on an AGV in performing the tasks of:

- Palletising
- De-Palletising
- Container Loading
- Mixed Pallet Sortation
- Mixed Pallet Order Picking

Which were identified from the site visits at the beginning of this project as areas such a system would be effective in:

- replacing manual labour
- eliminating OH&S risks
- improving container loading times and efficiencies
- improving traceability
- improving quality by eliminating carton damage

6 Impact on Meat and Livestock Industry – now & in five years

During the plant visits that were performed as part of Milestone 1 of this project a desire to eliminate as much labour as possible in the areas of

- Palletising
- De-Palletising
- Container Loading
- Mixed Pallet Sortation
- Mixed Pallet Order Picking

while maintaining or improving the time taken to perform these tasks was expressed.
Using container loading as an example, the potential benefits of automating this function would include:

- Labour – estimate replacing 3 operator(s) per working shift
- OH&S – reduced injuries and accidents
- Rates – container loading times could be quicker, improving loading dock turnaround time & carton cooling efficiencies
- Improved efficiencies – efficient carton loading consistent and repeatable operations
- Traceability – controlled operations each carton scanned and catalogued (time & location), eliminating potential 'lost product'
- Quality – reduced manual handling promotes better quality end product (reduce carton damage)
- Automation – provides ideal platform for carton automation (Chiller, Freezers, Sortation, Palletising)

While automating the sorting of mixed pallets or order picking would have the following benefits:

- Reduction in labour – the robot could be set the task of sorting or order picking with minimal operator intervention.
- Improved OH&S – reduced injuries and accidents
- Improved rates – pallet loading times could be quicker, improving turnaround time & carton cooling efficiencies
- Improved efficiencies – efficient carton loading consistent and repeatable operations
- Traceability – controlled operations each carton scanned and catalogued (time & location), eliminating potential 'lost product'
- Quality – reduced manual handling promotes better quality end product (reduce carton damage)

7 Conclusions and Recommendations

As can be seen from the demonstration conducted at MAR's workshops with a robot mounted on an AGV, there is great potential for the use of such a system in the areas of:

- Palletising
- De-Palletising
- Container Loading
- Mixed Pallet Sortation
- Mixed Pallet Order Picking

in red meat plants.
MAR recommends further work be carried out particularly, initially, in the container loading area to determine the best configuration for automating the delivery of cartons to this area and the loading of these cartons into the container.