



An Investigation into PLC Driven Automated Industrial Sorting

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DECLARATION

I, Aneurin Creed declare that I am the sole author of this Project; that all references cited have been consulted; that I have conducted all work of which this is a record, and that the finished work lies within the prescribed word limits.

This work has not previously been accepted as part of any other degree submission.

FORM OF CONSENT

I Aneurin Creed hereby consent that my Project, submitted in candidature for the BEng (Hons) Electrical and Electronic Engineering degree, if successful, may be made available for inter-library loan or photocopying (subject to the law of copyright), and that the title and abstract may be made available to outside organisations.

Abstract

The aim of the following report is to solve the problem of designing and developing a system whereby an industrial sorting process is completely automated from sorting to storage. If it is possible, this report will analyse to what extent this would be an effective process in the design and development for potential factories.

Some of the main objectives of the factory system are:

- Sort the incoming feed of parcels on to four different routes based on size and weight.
- Organise the parcels uniformly onto their respective pallets.
- Tag a completed pallet with a RFID tag.
- Merge separate lanes of loaded pallets into one lane where they will await storage.
- Store complete pallets in reference to RFID tag.

This project has been undertaken using the virtual simulation software Factory.IO, in which the virtual factory has been designed. Once the initial build was complete, Siemens TIA was used to programme the factory using ladder logic in order to meet the objectives. The successful virtual simulation of this factory designed within Factory.IO proves that this design would be applicable in the real world.

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Introduction

In order to design an automated industrial sorting system, I will be using Factory.IO as the software to simulate the factory. This software comes equipped with an array of components that can be arranged in any orientation to build a working factory. The factory will demonstrate the sorting abilities that can be programmed by a PLC module. The factory I am designing will receive 4 different types of parcels; pallet boxes, small boxes, medium boxes and large boxes. The small and medium boxes are of the same height but differ in mass. All of the parcels will initially be separated according to height, then the small and medium boxes are split by weight. Once all four parcels are separated, they are uniformly stacked onto their respective pallets before subsequently being stored away in an automated racking system at the end of the sorting process. In addition to sorting and storing these parcels an RFID system will be incorporated that will be used to aid the storage sequence as well as an HMI to give real-time feedback of the status throughout the sorting process.

Research and Literature Review

There are several companies that currently specialise in creating fully automated PLC-driven sorting systems. Companies tend to use a wide range of different components that allow for customisable systems that can be adapted for a range of different industries. Listed below is research relating to the main companies used to drive the research behind this design and the consideration of components used in the project.

Honeywell

Honeywell has a vast product selection. Within their sortation systems they have their Transnorm Sorting Modules (TSM). Honeywell's Transnorm Sorting Modules prides itself on being affordable, easy to install and highly scalable. Due to this Honeywell state that they have found a gap in the market for companies who have either a shortage of budget or space but still require a high throughput sorter on site. Honeywell claims that their system can achieve up to 6,500 PPH (parcels per hour). This design allows for a system that is easy to install, adapt, extend and replicate whilst handling a large input of incoming parcels. Highly configurable sorting modules allow for a wide customisation of uses.[1]

Modules such as their Wheel Divert Sorter provide consistent, jam-free handling of smaller products. The system uses pneumatically actuated urethane pulleys which sort and orientates packages upon an input command.[2]

Another compatible module is the Cross Belt Sorter. This conveyor system is built up of individual cross belt carts along a continuous belt. As the conveyor travels through a factory, each individual cart can be loaded or unloaded as required. Honeywell says that their “Patented “dynamic discharge compensation” enables precision discharge for significantly improved sortation accuracy and minimal manual touches”[3]

In addition to the TSM system that Honeywell has to offer they also have storage solutions such as their One-level Shuttle or (OLS) System which is capable of storing and retrieving items from single and double storage. This increases the storage space a factory has access to and allows for inventory turnover. Items are loaded onto a cart and then the cart transports the item to its slot. [4]

Dematic

Similar to Honeywell, Dematic's products page advises that their range of products are scalable and can be configured for low, mid, or high rate applications and are appropriate for small, medium, and large companies doing business in a variety of market sectors.

Dematic's Case & Package Conveyor has a durable design that extends equipment life and dematic claims that their systems running 24/7 will last decades. Their system has top-down access which makes maintenance easy. Their system is also compact which optimizes the footprint of the factory. [5]

Dematic's Pallet Conveyor has the ability to handle very heavy loads with extreme precision, this ensures that the items are safe, and the pallet can be stacked full without worry about the conveyor struggling.[6]

Dematic's Unit Load AS/RS is at the front of customizable industrial storage. This system can work independently round the clock storing, replenishing and retrieving items for orders. It also perfectly integrates with immediate human interaction during shift hours. The racking access it works with is completely customizable and can also be refrigerated.[7]

Beumer Group

The third company I found was Beumer Group.

Beumergroup prides itself for having High-speed parcel sorting systems that come in many designs to fit the exact needs for any business that may require a sorting system .

BG LINE SORTER is advertised as a unique solution which combines a conventional conveyor system with the handling capabilities of a high-speed cross-belt sorter. The modular design means users can expand and adapt floor plans to increase production or modify to new products.[8]

BG SORTER® COMPACT CB integrates its line sorter technology in a new alternate design. The compact CB is a line sorter but in an oval shape, with a narrow pitch and small radii it optimises the smallest of spaces and negates the need for additional storage. [9]

BG Sorter ET Tilt-Tray is said to be able to increase throughput and efficiency with its universal carry tray. Its closed deck design allows it to safely carry any item that fits within it. The tipping function is fast and completely adjustable with its variable speed control ensuring loading and unloading is speedy and accurate.[10]

Methodology

In order to complete the outlined objectives Factory.IO was used to construct a real-time virtual simulated factory. Based on research of companies currently in the field, I have selected several components and mechanisms to create my system. Factory.IO contains all the components needed to make the design fully automated and allows for a simulation of random incoming parcels in an attempt to replicate a real life situation. Once the design layout had been replicated in Factory.IO, Siemens TIA was then used to begin programming. The programming was largely completed through a trial and error method, working through the design in stages in order to develop the program and work out the location of the sensors. This proved to be advantageous as often the programme can dictate the components location. Working in this way also allowed for frequent testing of different sections of the design at different stages. For example, if a small change was made and the programme did not function properly, it was easy to back-track to previous steps and identify the difference that had caused the issue. However, the trial and error approach to programming also had its disadvantages in that a lot of the problem solving had to be done alongside the placing of the sensors, as time had not been taken to anticipate some outcomes when beginning to programme the software.

Siemens TIA was selected for this project as it is a trusted industry-standard software that can be used to programme and virtually simulate PLCs for industrial application. Within this software, ladder language was then used to programme the simulated PLC. Also known as ladder logic, this form of programming is

graphical and requires no prior knowledge of other coding languages. A useful feature of ladder logic is its ability to create an animation that can show live 'power flow' through the networks. This made it easy to find faults such as conflicting signals, timing errors and incomplete rungs, which complimented my trial and error method nicely.

Design & Development

Initial Design Diagram

Initial design made using Microsoft Publisher

This diagram was created using microsoft publisher and was the basic starting point for the design of the layout of the factory. In order to make this sorting system fully automated, several components had to be involved in the layout, which have been outlined in the key for this plan.

Final layout made using Factory.IO.

Stage 1 - Receiving the Parcels and Sorting

The first thing to consider when designing the layout is the incoming objects. The factory has been designed to receive 4 different types of parcels; pallet boxes, small boxes, medium boxes and large boxes. The small and medium boxes are of the same height but differ in mass. All of the parcels must be separated in order to be stored away.

In order to accommodate the sorting of the 4 different parcels, a network of conveyors is needed to transport parcels through the factory. Following their entry on the first conveyor, two pop-up wheel sorters are needed to split the parcels. Initially, pop-up wheel sorter number 1 is used in conjunction with a light array, allowing the system to sort the parcels by height and direct them to their respective conveyor. Pallet boxes will be sorted to the left, large boxes will be sorted to the right, and both small and medium boxes will continue to a second pop-up wheel sorter as they are the same height.

A light array is used before reaching pop-up wheel sorter 1 to sort the boxes based on their heights

The 4 parcels are split in 3 directions based on their height

Pop-up wheel sorter number 2 is then used in conjunction with a conveyor scale which gives a voltage output based on the weight of the parcel, thus enabling the system to differentiate between two different weight categories in which the parcels fall. The small parcels are then sorted to the left, and medium to the right.

A parcel on the conveyor scale before reaching pop-up wheel sorter 2. Boxes on the conveyor scale trigger the diffuse sensor, causing them to stop briefly on the scale in order to read the weight.

Stage 2 - Palletisers

Parcel count- pallet release

Once the parcels have passed the initial sorting stage, another round of conveyors transports them to the palletising stations where they will be uniformly stacked. The parcels pass a diffuse sensor which counts how many parcels pass the sensor and releases one pallet per max parcel load.

The first parcel passes the diffuse sensor on the incline conveyor causing a pallet to be released.

The max load for each pallet is different depending on the parcel size, and the diffuse sensor counter is programmed accordingly.

Pallet boxes - for every 12 boxes, 1 pallet gets released.
 Small boxes - for every 6 boxes, 1 pallet gets released.
 Medium boxes - for every 4 boxes, 1 pallet gets released.
 Large boxes - for every 4 boxes, 1 pallet gets released.

Parcel orientation

In order for the parcels to be loaded, they must first be oriented correctly to fit on the pallet. To decide the orientation of the individual parcels on their respective pallets, consideration had to be taken of the way that different size parcels would fit

For example, the large boxes being perfectly square meant that as long as their orientation is not on an angle, then they can be easily loaded without being turned a certain way.

The large square parcel approaches the palletising station at an angle and is oriented by wheel aligners to fit uniformly on the palletiser conveyor.

Whereas, in considering the pallet boxes, it was decided that they should travel with the shortest end forward as this allowed for greater control over their positioning. As the small and medium boxes are oblong in shape, they are oriented in the same way as the pallet boxes.

The pallet box approaches the palletising station at an angle and is oriented by wheel aligners to fit uniformly on the palletiser conveyor.

Loading pallets onto the elevators

For each sized parcel during the orientation process, the released pallet travels along a roller conveyor. On route to the palletiser elevator a pallet will pass a diffuse sensor which is used to count how many pallets have been released. The sensor also works in conjunction with the previously mentioned parcel counter to decide when a pallet should be released.

The diffuse sensor detects the pallet and adds 1 to the pallet count.

Once the pallet reaches the palletiser it comes into contact with an in built capacitive sensor (1aP Back lim). When this sensor is triggered it starts the elevator chain, pulling the pallet towards the second capacitive sensor (1aP Front lim). When this sensor is triggered the chain stops, holding the pallet on the elevator.

The pallet approaches the elevator. Once both sensors are covered, the pallet will stop.

Elevator Ascend

With the pallet in this position, both inbuilt sensors are on. This results in the elevator activating the ‘move to limit’ and ‘elevator ascend’ in-built actuators, causing the elevator to move to its highest position. Once the elevator has reached the desired position, it is ready to receive the parcels.

Elevator lifting pallet to its highest position.

Loading Parcels / Layer 1

Once parcels have been oriented correctly, they pass a diffuse sensor which counts the parcels as they are being loaded. The number of parcels loaded per row and the number of rows per layer will depend on the parcel size.

Row 1 waiting to be pushed

Once the limit has been reached for a row of boxes, a signal is sent to push the row of boxes from the conveyor to the palletiser plate, where it will wait until the layer is complete and ready to be loaded onto the pallet.

Row 1 being loaded onto palletising plate

Layer 1

Pallet boxes	- 2 boxes per row, 3 rows per layer
Small boxes	- 1 box per row, 3 rows per layer
Medium boxes	- 1 box per row, 2 rows per layer
Large boxes	- 2 boxes per row, 2 rows per layer

Layer 2

Pallet boxes	- 3 boxes per row, 2 rows per layer
Small boxes	- 1 box per row, 3 rows per layer
Medium boxes	- 1 box per row, 2 rows per layer
Large boxes	- only 1 layer

The system knows a layer is complete by counting the number of rows pushed onto the plate. Once the layer is complete, the palletiser clamps the boxes into position and the plate doors will slide open. Once the plate doors are opened, the clamp is released, dropping the parcels onto the pallet beneath.

First layer in position on palletising plate

Elevator Part Descend

When the clamps have released, a signal is sent that incrementally descends the elevator depending on the height of the layer in order to fit beneath the plate level (the pallet boxes drop by 1, the small and medium drop by 2 and the large boxes move to the bottom limit). Once parcels on the elevator have descended below the plate level, the plate doors will close ready to receive the next layer of parcels.

First layer layer of parcels below closed plate

Loading Layer 2

The loading of layer 2 is identical to layer 1 for the small and medium boxes, but the pallet boxes differ in orientation in order to achieve a more stable fit. The original aim was to also stack in a lattice-type formation the small and medium boxes as the dimensions of the boxes suited this formation. However, the in-built turner on the palletiser was not able to turn the boxes 90 degrees as desired due to the length of the turner in comparison to the size of the boxes. Therefore, the medium and small boxes are stacked with identically oriented layers, which caused the pallet load to be slightly less stable.

Palitiser loading the second layer of parcels

Elevator Full Descend

Once layer 2 is complete, the previous loading procedure is repeated and the layer will again drop below the level of the plate. Then, the palletiser will activate the 'move limit' and 'elevator descend' actuators, causing the elevator to move to its lowest positions. When the full pallet has reached the lowest position, the elevator chain begins moving the full pallet off of the elevator onto a roller conveyor.

Full pallets exiting elevator

Stage 3 - Merging Palletisers Output

Turntables and roller conveyor system used to merge full pallets

Turntable Loading

Each pallet is then taken along its respective conveyor towards a turntable. These were used as a solution to merge the four lanes into one final roller conveyor leading to the stacker crane for storage. Initially when the pallet leaves the palletiser, it triggers another diffuse sensor which counts the number of pallets leaving the palletising station. This will also send the signal to turn on the roller conveyor which transports the pallet to the turntable. Once a pallet has reached its turntable, a loading and unloading procedure will commence. First, a diffuse sensor is used to detect the presence of a pallet. If the turntable is not in a position to load the pallet, the loading roller conveyor will stop until the turntable is aligned to

receive a pallet. There are 3 conditions to loading the pallet; the turntable must both be in the correct position and be empty and the diffuse sensor must have been triggered by the detection of a pallet.

Turntable in wrong position, pallet waiting

When these three conditions have been met, the roller conveyor pushes the pallet onto the turntable, activating the first capacitive sensor. The activation of the first capacitive sensor causes the rollers on the turntable to push the pallet along further until it reaches the second capacitive sensor. When the second capacitive sensor is triggered, the rollers on the turntable will stop. The pallet is now fully loaded onto the turntable.

Turntable in correct position, pallet loading

Turntable Turning and Unloading

Once the pallet is fully loaded and both capacitive sensors are triggered, the turntable will begin to turn 90 degrees anti-clockwise. Once this quarter rotation is completed, a signal is sent to activate the turntable's rollers and the intermediate roller conveyor, thus unloading the pallet from the turntable. Once the second capacitive sensor has deactivated due to the pallet being unloaded, a signal is sent which returns the turntable to its original orientation.

Turntable turned 90 degrees anticlockwise and unloading full pallet onto intermediate roller conveyor

As there is a turntable at the end of each lane, a decision was made so that if two pallets arrived at the same turntable from different conveyors, priority would be given to the pallet arriving from the intermediate conveyor. This means that pallets from the same palletiser should never queue on the same loading roller conveyor, thus avoiding too much traffic in one lane.

Pallet Box Turntable

This turntable differs from the others in that when a fully loaded pallet of pallet boxes reaches the turntable, the aim is to continue the direction of travel on to the final roller conveyor that leads to the stacking crane. The pallet boxes arriving at the pallet box turntable are loaded as previously discussed, but turn 90 degrees clockwise to join the final loading conveyor.

Stage 4 - Storage System

Once the pallets have been merged onto the final roller conveyor, the pallets can be loaded onto the crane and then moved to a storage position before being unloaded. Along the final roller conveyor, there are 5 diffuse sensors. These are used to stagger the positioning of loaded pallets waiting to be stored. If a pallet reaches the closest diffuse sensor to the stacking crane, the loading procedure of the stacker crane will begin. If there are pallets travelling towards the stacker crane and the stacker crane cannot be loaded at that time, a queue will form. Each sensor, when triggered, will stop the section of roller conveyor immediately behind it, thus forming a staggered queue.

Stacker crane not in the loading position, full pallets form a queue

Between the roller conveyor and the stacker crane, there is a load conveyor. This allows for the pallets to be picked up by the stacker crane arms and loaded onto the stacker crane cart. When a pallet has been lifted by the stacker crane and has reached the middle limit of the cart, it is ready to be moved into position for storage. The stacker crane stores each pallet on the racking. Its position on the racking is determined by the order in which it arrives at the stacker crane, i.e 1st pallet in position 1, 4th in position 4. This is calculated by counting the number of times the diffuse sensor at the end of the loading roller conveyor is triggered. This integer is then moved to the stacker crane's 'target position' actuator, thus forming the control output for the location of the stacking crane.

Stacker crane loading the cart.

Stacker crane in a position to unload a full pallet.

Pallet unloaded stacker crane cart empty.

Stage 5 - HMI

Within Siemens, a virtual HMI has been created in order to give the user basic control over the factory's operation as well as displaying live updates as the factory runs. Two screens have been designed. The first screen, titled 'box sort', allows the user to start or stop the simulation and reset all counters and actuators within the programme. On this page, there are also several counters which give live updates to the user about the number of boxes within the system. The sorting process is also indicated using pilot lights. The second screen, titled 'palletisers', displays the status of the palletisers process. This, again, uses counters to display the number of boxes arriving and the number of boxes loaded for each parcel size. Pilot lights are also used here to indicate the rows and layers of parcels as they are loaded onto the pallet. Each page also features a navigation to switch between the two screens.

Box sort screen.

Palitiser screen.

Evaluation

My project has shown that designing and running a fully-automated virtual factory is definitely possible through the means of these softwares. However, although most of my objectives were met through the simulation, as my design in Factory.IO became more complex, there were some objectives that the software could not handle. For example, I was successful in creating a separate, fully functioning RFID system where I was able to write and read individual RFID tags. One of the main issues faced was the fact that Factory.IO was not able to handle the quantity of input and output tags that my initial design required. This resulted in me having to partially compromise two of my objectives (tag a completed pallet with RFID, store complete pallets in reference to RFID tag) despite knowing that this application of RFID tags was possible. This was an unforeseen problem which took a relatively large amount of time to identify. When looking more closely at these issues, it proved to be a flaw within Factory.IO as all potential conflicting signals were eventually ruled out.

In evaluating my project against the research gained in the literature review, all the sortation and storage methods mentioned in the research that I included within my factory's design performed as expected. I believe that Factory.IO and Siemens TIA combined are effective tools in the design and development of proposed factories, although, I would recommend using Factory.IO to simulate segments of factories separately. However, I also acknowledge that a downside to having multiple simulations is that faults within the system may not be identified as different sections are not shown interacting with one another. With this in mind, it may be that the best course of action is to create a fully functioning simulation with as few inputs and outputs as possible. Despite this, in situations where the design is complex and unable to be simplified, an alternative to Factory.IO should be considered.

If I was to recreate this project, I would be more organised and precise in that I would develop a more detailed plan for the programme that runs the simulation. This would allow for some potential faults to be eliminated before the simulating stage and aid in problem solving whilst programming. As aforementioned, I would also split the simulation into more manageable sections as to not overload Factory.IO.

Conclusions and Recommendations

This report followed a process from planning a basic initial design right through to creation and development of a simulated factory. Throughout the project, various challenges were faced in the programming, which could have been potentially been avoided by a more detailed initial plan.

Conclusions in relation to objectives:

Sort the incoming feed of parcels on to four different routes based on size and weight

This went exactly as planned and required minimal planning as it was simple to programme.

Organise the parcels uniformly onto their respective pallets

This was more challenging than expected and required a lot of consideration of multiple timings, meaning that there were very small windows in which to execute the correct outputs. To achieve this objective, I believe that my use of the palletiser and elevator system, although very difficult, proved to be very effective means of achieving this objective.

Tag a completed pallet with a RFID tag

As previously discussed, this objective, although proving attainable, could not be implemented alongside the already complex simulation.

Merge separate lanes of loaded pallets into one lane where they will await storage

The turntables were used to achieve this objective. This solution presented several challenges as several considerations had to be made towards multiple items causing conflicting signals. Due to the design, one turntable could be in a situation where full pallets would attempt to load from different positions simultaneously. Conditions for loading had to be implemented and a priority to the right was incorporated to resolve the inevitable conflicting signals.

Store complete pallets in reference to RFID tag

This objective was partly achieved through the use of a stacker crane which was successful in storing full pallets. However, due to the previous objective being unattainable through the software, the implementation of RFID tags had to be left out.

In terms of recommendations, researching into other softwares that have the capacity to virtually simulate a factory design would be valuable. If used in an industry setting, it would be beneficial that the software be able to handle more complex designs. Further research into ladder logic could also be beneficial in simplifying some of the code, making it slightly more efficient and saving time.

Reflection

I feel that this project has developed my knowledge of both Factory.IO and Siemens TIA, making me more comfortable with the application of both software's features. If I was to use these again, I am more aware of the shortcomings of Factory.IO in its inability to handle large quantities of inputs and outputs, which I could use to my advantage when planning any further projects. I am now more aware of the intricacies of Siemens and far more confident in using it as a creative tool to produce a functioning programme which can achieve specific objectives. I enjoyed using factory.io as it is a very intuitive software to use, however, the project application in this scenario clearly pushed it beyond its capabilities. The biggest shortcoming of the project was not being able to implement the RFID system in the final factory. This was a part that I was particularly excited about and knowing that it was an achievable objective made it more frustrating to leave out. I believe that incorporation of an RFID system would have improved the overall efficiency of the factory and provided a further avenue for development outside of the initial objectives.

I think this project could definitely have been improved with greater planning and simplification in the interest of a greater level of efficiency. I believe that this method of virtual simulation and programming combined is an effective tool in the process of planning a real factory, as it could be used to save both time and money as well as revealing unforeseen shortcomings.

References

- [1] Sps.honeywell.com. 2021. *Transnorm Sorting Modules*. [online] Available at: <<https://sps.honeywell.com/us/en/products/automation/solutions-by-technology/sortation-systems/transnorm-sorting-modules>> [Accessed 23 April 2021].
- [2] Sps.honeywell.com. 2021. *Cross Belt Sorter*. [online] Available at: <<https://sps.honeywell.com/us/en/products/automation/solutions-by-technology/sortation-systems/cross-belt-sorter>> [Accessed 23 April 2021].
- [3] Sps.honeywell.com. 2021. *Cross Belt Sorter*. [online] Available at: <<https://sps.honeywell.com/us/en/products/automation/solutions-by-technology/sortation-systems/cross-belt-sorter>> [Accessed 23 April 2021].
- [4] Sps.honeywell.com. 2021. *One-level Shuttle (OLS) System*. [online] Available at: <<https://sps.honeywell.com/us/en/products/automation/solutions-by-technology/asrs-systems/one-level-shuttle-ols-system>> [Accessed 23 April 2021].
- [5] Dematic.com. 2021. *Case & Package Conveyor | Conveyor Systems*. [online] Available at: <<https://www.dematic.com/en-gb/products/products-overview/conveyor-systems/case-and-tote-conveyors/>> [Accessed 23 April 2021].
- [6] Dematic.com. 2021. *Pallet Conveyor - Conveyor Systems*. [online] Available at: <<https://www.dematic.com/en-gb/products/products-overview/conveyor-systems/pallet-conveyor/>> [Accessed 23 April 2021].
- [7] Dematic.com. 2021. *Unit Load AS/RS | Storage Systems*. [online] Available at: <<https://www.dematic.com/en-gb/products/products-overview/storage-systems/unit-load-asrs/>> [Accessed 23 April 2021].
- [8] Career, J., Us, A., Systems, P., Support, C., hub, K., industries, A., Career, J., Us, A., us!, C. and Person, Y., 2021. *BG Line Sorter | BEUMER Group*. [online] BEUMER Group. Available at: <<https://www.beumergroup.com/i/bg-line-sorter-15873/>> [Accessed 23 April 2021].
- [9] Career, J., Us, A., Systems, P., Support, C., hub, K., industries, A., Career, J., Us, A., us!, C. and Person, Y., 2021. *BG Sorter® Compact CB | BEUMER Group*. [online] BEUMER Group. Available at: <<https://www.beumergroup.com/i/bg-sorter-compact-cb-50469/>> [Accessed 23 April 2021].
- [10] Career, J., Us, A., Systems, P., Support, C., industries, A., Career, J., Us, A., us!, C. and Person, Y., 2021. *BG Sorter ET Tilt-Tray | BEUMER Group*. [online] BEUMER Group. Available at: <<https://www.beumergroup.com/i/bg-sorter-et-tilt-tray-35149/>> [Accessed 23 April 2021].