Flexible Automation of Kitting Process at Arla

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Abstract

This paper encapsulates the problem definition, analysis and solutions conception and bench marking, of the need for improvement and automation of the kitting processes at the Arla distribution center in Hobro. Operational inefficiencies stemming from a high degree of manual labour exist within the current product picking setup. The underlying objectives were to identify the gaps in efficiency in the company's standard operating procedures and to propose improvements to address those gaps with the potential implementation of increased automation in the picking processes. A detailed analysis of the facility's operations was completed to establish baselines for current performance metrics, to enable the development of more efficient picking models, that employs varying degrees and combinations of human workers and autonomous mobile robots (AMRs). Proposals are also put forward to migrate the current order-based picking practices to zone-based picking and hybrid picking models. Technical simulations were carried out to replicate the current operational baseline, which served as the platform to validate solution proposals that would target tangible improvements in key performance metrics such as manpower and automation requirements, overall cycle and lead times, utilization rates, travel distances and any safety considerations. Conclusions are made with recommendations on future steps for the long-term realization of the foundations of the goals laid out in this project.

Keywords: Distribution center operations, Warehouse, Kitting, Picking, Order-based Picking, Zone-based Picking, Autonomous Mobile Robots, AMRs

1. Introduction

Arla is a multinational dairy cooperative headquartered in Viby, Denmark, owned by farmers across Scandinavia, western Europe and the UK. The company manages its own complete 'farm-to-store' supply chain, including the production and logistics, of dairy products to stores nationwide in Denmark.

The Arla Hobro terminal consists of a dairy production unit and a distribution center, housed under the same roof. Each business unit, however, operates independently of each other, run by different management teams.

The scope of this paper is centered around the activity specific to the kitting/picking areas within the distribution center at the Hobro terminal. The sequence of processes involved in this area are currently manual-intensive. The company expressed a desire to investigate opportunities for increased automation in the picking area of the distribution center to help increase overall efficiency and performance, and potentially reduce error rate and human impact on operations, while also aspiring to achieve any tangible improvements in safety, timing and costs.

1.1 Problem statement

There is a need for improvements and increased automation in the Arla Hobro distribution center's picking processes to minimize overall inefficiencies stemming from highly manual-intensive methods currently in place.

1.2 Desired outcomes

- Working principle of autonomous mobile robot (AMR) to be used in the distribution center picking area
- Detailing of environment requirements for AMR integration in current distribution center layout
- Picking model conceptions for different combinations of human and AMR working

2. Industrial Practices

The primary concept that most distribution center based operations are governed by, comes down to the system of 'picking' that is employed to transfer product from the storage zones to the staging and loading area for the delivery vehicles. Broadly speaking, picking systems can be classified into two main types: order-based picking and zone-based picking. [1]

2.1 Order-based picking

The mechanism behind order-based picking systems is that each order is catered to at a time by an assigned picker, who fulfils every order by picking every product on a provided list while going through each respective storage zone within the facility in which each product on the list is stocked.

Each order that a picker caters to is referred to as a ‘pick line’. While each pick line is typically dedicated to a single customer, each customer can have multiple pick lines assigned to multiple pickers based on the size of the overall order and the need to divide it into discrete sizes based on the size of the containers used by the pickers in the storage zones. Order-based picking systems are sometimes referred to simply as ‘pick-and-pack’ method, since the same entity is carrying out both aspects of the operation.

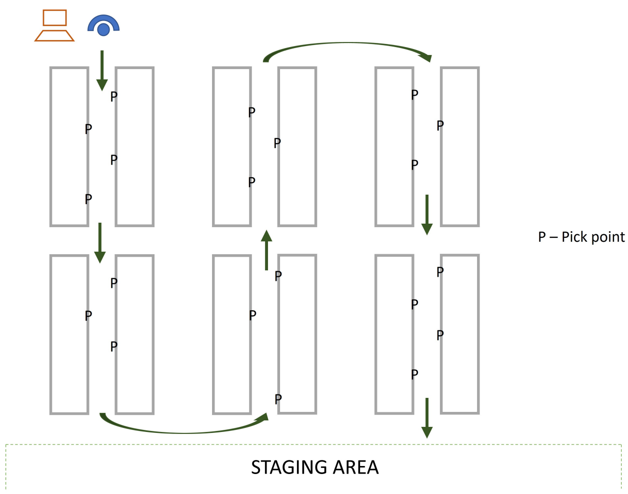

Fig. 1 Order-based picking schematic

Figure 1 above depicts a simple order-based picking setup. Each order or pick list is retrieved at a central terminal. The list may contain all information related to each pick line in its entirety, such as order quantity, product type and quantity, product storage location etc. Order-based picking can also work in conjunction with voice-directed picking systems.

The picker then proceeds to retrieve the movable container that will house all the product they pick from each storage zone for each pick line. After that, the picker traverses the route required through the storage zones according to the pick list provided to pick and pack each product in its desired quantity into the handling container. After the picker has completed their entire route covering all pick points assigned for each pick line, the fulfilled order in the form of a filled container with product corresponding to the order list is transferred to the staging area for it to be loaded into the shipping truck.

While order-based picking’s greatest strength lies in its simplicity, its underlying drawbacks with regard to large product variety in warehouse storage zone, long travel times for each pick line in large warehouse settings, high congestion and traffic due to typically similar routes during picking, and typically higher error rates due to dependency on picking accuracy mean that this system of picking is the less preferred alternative in most established distribution centers. The drawbacks of order-based picking can be addressed by a different system called zone-based picking.

2.2 Zone-based picking

The primary difference between order-based and zone-based picking is how the storage zones are divided with respect to picking routes. As mentioned, while order-based picking systems work on the principle of pick and pack, zone-based picking systems operate on the basis of ‘pick-and-pass’. This means that the entire storage area of the warehouse is divided into smaller regions called ‘zones’, within which there is a systematic arrangement of product storage, usually organized in order of product size, or frequency of being ordered.

Each zone is typically manned by one or two pickers, or maybe more depending on the size of the zone, and these pickers’ movements are restricted to within their designated zone. The reasoning behind the system being referred to as a pick-and-pass setup is that each picker picks product only within their picking zone and creates a sub-order or zonal pick line that then gets aggregated by a centralized collector, i.e., each picker ‘picks and passes’ their respective subset of the entire order to a collector who has their own route throughout the facility that involves only going to every zonal pick-up point to complete each order.

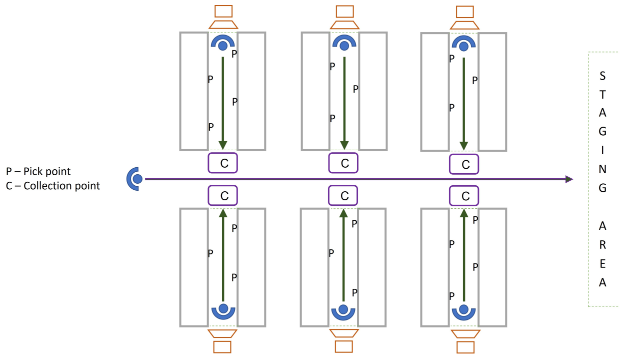

Fig. 2 Zone-based picking schematic

Figure 2 depicts a typical setup for a zone-based picking system. Each zone has its own designated picker who would typically start from one end of their respective zone, picking and fulfilling the subset of the overall order list while moving towards the other end, typically where the 'pass' or zonal drop-off station is located. A centralized collector or aggregator would pick up each subset of the overall order from every zonal pass station and transfer the aggregated order to the staging area for shipping.

By configuring storage zones according to facility-specific requirements, the drawbacks of order-based picking can be worked around. Having zones set up in a manner where the highest frequency products are stored in zones closer to the staging area and having more picking resources in such a zone, could greatly reduce the overall travel time for most pick lines. Picking accuracy also tends to be higher as the potential error rate for a lower spread of product variety in each zone means that pickers tend to have better command over their zones in terms of knowledge of product placement and thereby an increased speed of movement. Overall traffic and congestion in order-based systems are also addressed by segregating and isolating each zone and eliminating the need for multiple pick lines to interfere with each other.

These two picking concepts will form the underlying basis for the solution proposals to address Arla's shortcomings in operational efficiency, and sets up the introduction of a hybrid picking concept that is put forward as the primary solution.

3. Analysis conducted

Analysis methods to garner information on the current state at the distribution center included:
i. Firsthand observations during peak shift operations of current layout, standard operating procedures and overall process flow;
ii. Data analysis on company-provided warehouse management system data for product storage configurations and picking volumes, manpower usage, lead times and cycle times, travel distances and activity heat maps;
iii. Simulations to replicate current setup and proposed concepts

3.1 Distribution center picking area

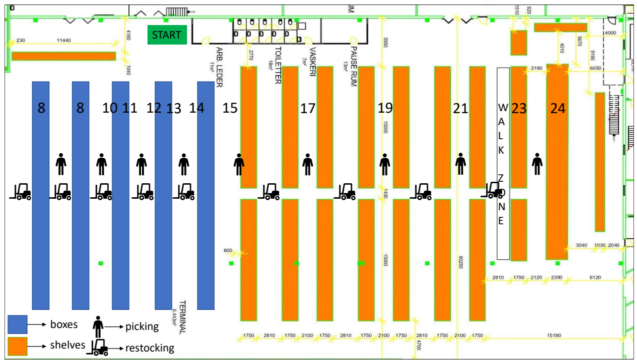

Fig. 3 Picking area.

The layout of the picking area within the distribution center is depicted in Figure 3. The picking area is segregated into two zones, the Box Picking area (represented in blue) and the Shelf Picking area (represented in orange). The division of aisles with the aisle numbers (8 to 14 in the Box Picking area and 15 to 24 in the Shelf Picking area) is also depicted in the figure.

Between the shelves in the Shelf Picking area, there are two types of aisles: picking aisles (with a symbol denoting a person in the aisle) and restocking aisles (depicted with a symbol for a forklift in the aisle).

Picking aisles are used only by pickers on foot during the kitting of the order. During the picking sequence, pickers find the correct product to be packed based on posted signs that contain an identifying picture, the product location and product number or designation.

Restocking aisles are wider than the picking aisles and they are used only by forklifts to restock products in the shelves when required.

3.2 Picking cycle description

A calculation of the average time to complete all the steps, from the time the label is generated to trigger the start of a picking cycle until the fulfilled order is transferred to the loading bay and then back, in one picking cycle (of one picker) was carried out.

Understanding the complete breakdown of tasks that a picker has to complete for one order would help in identifying aspects of the cycle that are contributing to the overall inefficiency, thereby highlighting the steps that could be eliminated, or replaced by a potential AMR to increase human utilization efficiency.

The overall sequence of operations from start to finish are broken down into 'movement' and 'picking' steps, following an alternating pattern of moving and product-picking steps, where each moving step corresponds to the time taken by the picker to move from one pick point in the storage zone to the next, and each picking step corresponds to the time taken by the picker to transfer the product in its desired quantity from the storage pallet to the handling container. The final step in every picking cycle corresponds to the movement that is required for the picker to walk the distance from the fulfilled order drop-off area back to the label printer for the start of the next picking cycle.

The overall average cycle time is calculated to be 488 seconds, or just over 8 minutes to complete one cycle from label to label, by one operator.

While conventional wisdom dictates that the term 'value-added' refers to those processes in a production facility that involve specific changes to the form, fit or function of a product throughout its value chain that translate directly to customer requirements, and all others are referred to as 'non-value-added', in a distribution center type environment such as Arla, the company uses the term value-added or 'travel-full' to refer to processes where any movement involves transportation of product, while non-value added or 'travel empty' refers to any movement that does not directly involve any product being moved.

The Gantt representation of the overall picking cycle timeline is represented below in Figure 4.

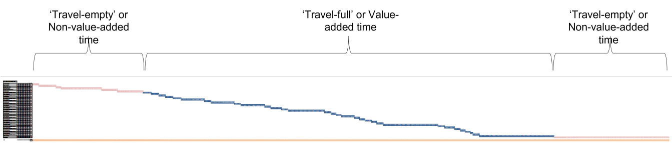

Fig. 4 Picking cycle Gantt

3.3 Discrete event simulation

As a tool of analysis and comparison, a simulation of the current setup was created using Enterprise Dynamics software. The data used in the simulation has been recorded through Arla's warehouse management system in the time span 26/04/2022-18:00 to 27/04/2022-05:00. It is assumed that the data given by Arla is representative of an average day. This data was sorted in a way that it could be used in a simulation environment, so that the picking process of each order is known. Thus, all of the product, picked through this day, were input into the simulation to generate a realistic picking cycle.

The purpose of this simulation was to obtain a baseline, which other simulations, based on the same base model, can be compared to. The simulation used can be seen in figure 5.

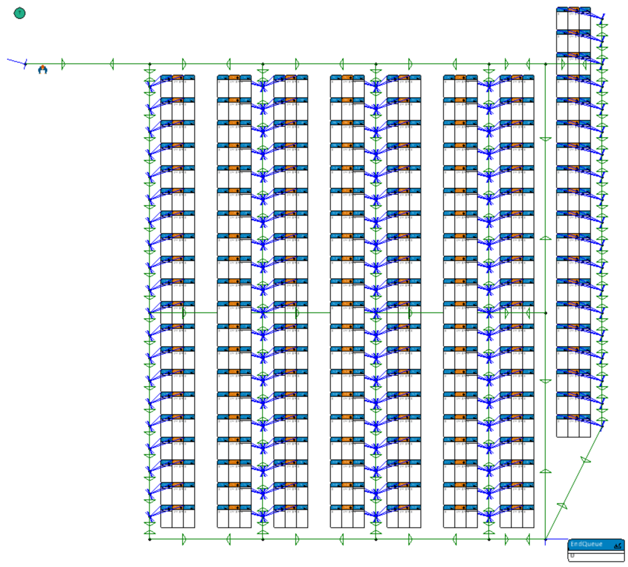

Fig. 5 Layout of the simulation of the current setup.

3.3.1 Assumptions

Assumptions made while creating the simulation are:

- Only picker and one cage have been used to simplify this initial simulation.
- Only aisles 15-23 have been used in the simulation since the aisles on either side will be changed in the foreseeable future. The layout of the changes have not been set yet.
- The distance used in the simulation is not fully accurate but it's within reason.
- From the data provided by Arla, the cycle time for picking each product and the number of products per picking line could not be extracted. Therefore, one product per picking line has been assumed, with a mean picking cycle time of a 5 sec.
- The speed of the pickers has been set to 1 m/s.
- The movement in the aisles are restricted similar to the current setup.

3.3.2 Simulation results

Results of the simulation are presented with a distribution chart in Figure 6, which contains the following information:

- Movement with the cage ("Travel full")
- Movement without the cage ("Travel empty")
- Picking products ("Picking")

- Simulated Run time: 7 minutes
- Picking % : 18 % = 1.26 minutes
- Travel with cage % : 61 % = 4.27 minutes
- Travel without cage % : 21 % = 1.47 minutes

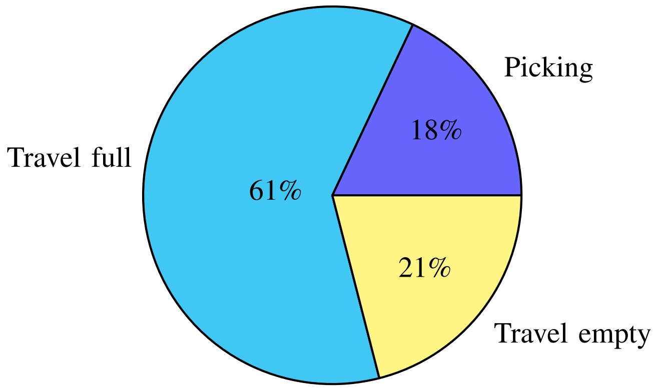

Fig. 6 Distribution of actions with one AMR.

For this concept 21 % of the time is spent on non-value-adding actions.

4. Innovation Proposition

Arla plans to field a proof of concept (PoC) for picking assisted by AMRs (Autonomous Mobile Robots) in the distribution center. AMRs are robots that can perceive its environment and travel without the need to be monitored by an operator or the need for a fixed predetermined path. The idea is to have AMRs assist the human pickers in the picking process, which woould reduce manpower requirements.

The PoC is based on a hybrid of order-based picking and zone-based picking concepts, depicted in Figure 7. In the PoC, the human pickers' movements are restricted to one aisle, or one section of an aisle, denoting a zone, while the AMRs will move the handling containers and travel through every zone on the same order-based picking pattern being currently followed at Arla, while each human picker packs their sub-segment of the overall order in their respective zone during the AMRs pass through that zone. This setup would lead to a drastic reduction in the need for human pickers when compared to the existing order-based picking setup at Arla.

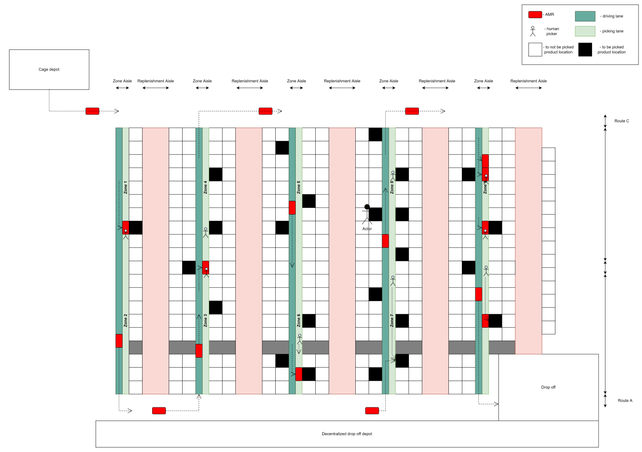

Fig. 7 Hybrid-based picking concept.

To evaluate the result of implementing the hybrid picking concept derived from the Arla's proof of concept, a simulation of the concept was developed. The simulation is based on the same data for orders, cycle times and restriction of movement as the simulation developed for the as-is setup. However, in this simulation, the four actions previously done only by humans have now been done in collaboration with AMRs.

4.1 Assumptions

Three new assumptions compared to the current state model have been made:

- Only one picker, one AMR and one cage have been used to simplify this initial simulation.
- The speed of both the human pickers and the AMR has been set to 1 m/s.
- The movement of the AMRs in the aisles are restricted similar to how the pickers move in the current setup.

4.2 Result

By introducing AMRs into the current setup, the total cycle time will increase. However, since the majority of the traveling including the non-value-added movements of the current picking cycle would now be performed by the AMRs, the theoretical man hours needed from the picker has been reduced. This means for this one cage, the time needed from the picker has been halved from 7 minutes to 3.75 minutes. This potential improvement is only possible if there are enough AMRs to ensure the pickers do not have any idle or waiting time.

4.3 Validation of Model

To validate that there is a possible configuration of the PoC that can outperform the current setup with the same number of workers, measured by the total simulated cycle time, an experiment was conducted. For the first iteration, one worker has been placed in each aisle. As a benchmark, the total cycle time of the simulated current setup with 5 pickers has been used, which gives the PoC a target time of 4.3 hours to beat with the same number of workers.

After simulating with a finite number of AMRs, the following data in has been extracted:

# of AMRs	Cycle Time (h)
1	26.2
2	13.6
3	9.5
4	7.5
5	6.5
6	5.7
7	5.3
8	5.0
9	4.7
10	4.6
15	4.3
20	4.0

Tab. I The cycle time as a result of number of AMRs

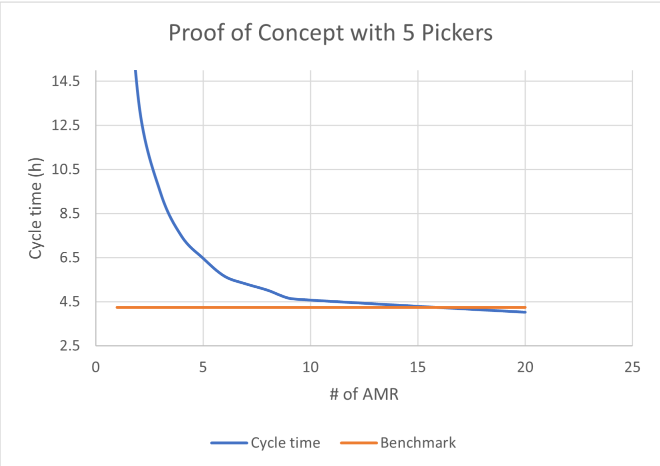

Fig. 8 *Cycle time as a function of number of AMRs*

As seen in Figure 8, the reduction of cycle time decreases dramatically after 7 AMRs with the point of diminishing returns being reached at about 15 AMRs. It is expected that this is due to bottlenecks accruing in some of the aisles. This has been verified by calculating the distribution of actions performed by the pickers in each aisle. In Figure 9 and 10, this has been illustrated with pie charts for configurations with 5 and 10 AMRs, respectively. The red portion represents the time spent waiting for the AMR, the yellow represents the time travelling to the AMR and the green represents the time spent picking the products.

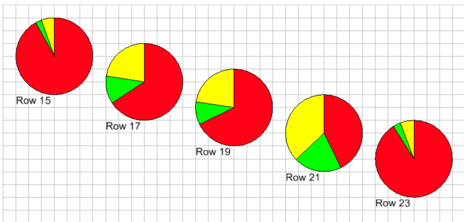

Fig. 9 *Distribution of actions with 5 pickers and 5 AMRs*

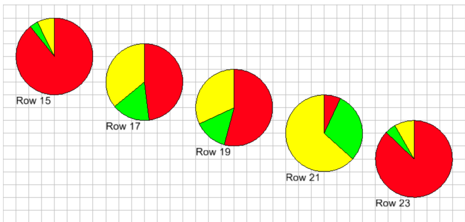

Fig. 10 *Distribution of actions with 5 pickers and 10 AMRs*

The first take away from the figures, is the obvious disparity between the aisles. This is due to the number of picks not being the same for each aisle. To achieve the most efficient configuration of this concept, a full reconfiguration of the product locations is necessary. The second thing to note is the high percentage of the human travel to the AMR, and the low percentage of waiting compared to the other aisles. This indicates that that the size of the zone should be reduced and/or an extra worker is needed. To verify this, a second iteration with 6 workers has been made. This time aisle 21 has been split into two with one picker in each zone. The remaining aisles still consist of one zone with one picker in each. The benchmark for this iteration is 3.6 hours which has been extracted from the total cycle of the simulated current setup with 6 pickers.

# of AMRs	Cycle Time (h)
1	25.6
2	13.1
3	9.1
4	7.2
5	6.0
6	5.2
7	4.6
8	4.4
9	4.2
10	4.0
15	3.4
20	3.1

Tab. II The cycle time as a result of numbers of AMRs

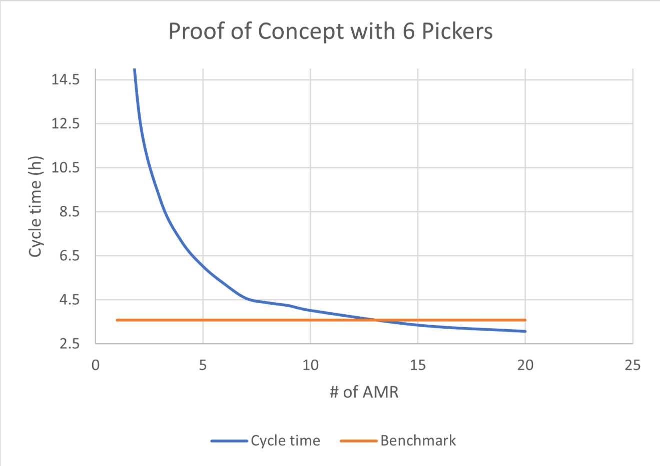

Fig. 11 *Cycle time as a function of numbers of AMRs*

Similar to the previous iteration the rate at which the cycle time reduces, decreases with the increase in the number of AMRs. However, for this iteration the point of diminishing returns is reached at around 13 AMRs. It is once again expected that the relation between cycle time reduction rate and numbers of AMRs are caused by bottlenecks. In figure 12 and 13 the distribution of actions in each aisle has been illustrated for a configuration with 10 and 15 AMRs respectively.

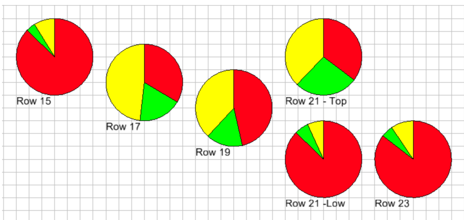

Fig. 12 *Distribution of actions with 6 pickers and 10 AMRs.*

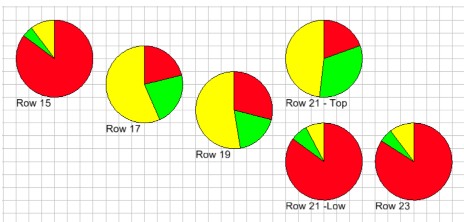

Fig. 13 *Distribution of actions with 6 pickers and 15 AMRs.*

As expected, the overall waiting time have been reduced as a result of the flow of cage. As seen in the previous figures, the workload isn't spread evenly throughout the aisles. This once again underlines the impotence of a reconfiguration of the product placement if the should perform at it's best. To make a conclusion to this experiment, three points should be made. Firstly, the placements of the products need to be changed. Secondly, there is ails have to be split into multiple zones as to reduce the percentage of traveling to the AMR. Finally, there is multiple configurations which will result in the hybrid concept being more efficient than an equivalent concept with the currant setup.

5. Conclusions / Future State

After the analysis of the distribution center picking area, it is concluded that facilities such as Arla Hobro, which are constrained by available space for expansion and improvement possibilities, can only be improved incrementally through conventional methods without the implementation of automated solutions. Furthermore, because of this, even generally available automated solutions can prove to be difficult to implement. For environments like this, there is a need for customised, turnkey automated solutions, which are typically cost-prohibitive and difficult to develop.

There are multiple possible roadblocks during the process of implementation and many potential problems can occur. When using the tools, like discrete event simulation, large data sets need to be analysed for an accurate representation of the working model. In this project, data was limited to a single shift, which likely wont give an accurate representation of real-world conditions, but still serves as a use case basis for reasonably accurate analysis of current states and proposed future solution bench marking.

As a conclusion to experiments made with the discrete event simulation of the hybrid picking, three points should be made. Firstly, the placements of the products need to be changed due to bottlenecks created in the high frequency of picking areas. Secondly, there is aisles that have to be split into multiple zones as to reduce the percentage of traveling time to the AMR. Finally, there are multiple configurations which will result in the hybrid concept being more efficient than an equivalent concept with the currant setup, so the implementation of AMRs, with good planning, can provide to be vital in increasing the efficiency of the distribution center.

5.1 Future state recommendations

With more time, data and experimentation, the same methods can be applied to develop more picking models. As a future consideration examples, three zone based picking models have been briefly considered as a potential solutions. Each model has different configurations on the basis of factors like number of AMRs and human pickers used, travel routes for AMRs and the number of zones. Decision about the model configurations were made with low level calculations and assumptions, and will need further research.

5.1.1 Zone-based picking - Model 1

In this setup, the picking area is divided into several zones, as shown in the Figure 14. Each zone is assigned to a picker and the picker must only pick products from the picker's assigned zone.

The distribution centre has two blocks – Block 1 and Block 2 as labelled in the Figure 14. There are zones in both of the blocks. The zones in block 1 have their corresponding handover locations in the middle cross aisle. The zones in block 2 have theirs in the bottom cross aisle.

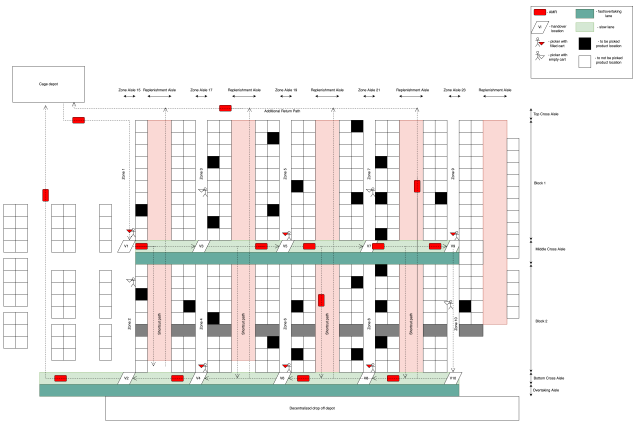

Fig. 14 Model 1 layout.

Cross aisles are pathways to move from one zone aisle to another, and they contain handover locations for each zone shown by parallelogram in the figure and marked as Vi. In total, there are three cross aisles: top cross aisle, middle cross aisle, bottom cross aisle. The middle and top cross aisle will be used by AMRs to move from one handover location to another (right to left in the figure). The bottom cross aisle will be used by AMRs, after finishing an order, to drive back to the cage depot to pick a new cage for the next order.

The middle cross aisle and top cross aisle consist of 2 lanes shown in dark green and light green. The light green lane represents the slow lane and is the default lane to be used and the dark green lane represents fast lanes which can be used for overtaking to avoid congestion and queuing. For convenience, top cross aisle may be called route A, middle cross aisle may be called route B and the low cross aisle may be called route C.

Since the zone pickers will be working on the same order simultaneously, the pickers will be given the information (via pick-to-voice system) about the products that must be picked from their zone for the order. Each picker will have a mini cart in which the products can be collected. The picker will pick each product as per the given information and move to the zone's handover location. The picker will either wait there for the AMR to come or place the collected product in the cage of the present AMR. After giving the confirmation signal that the product has been placed in the AMR, the picker will get instructions for the next order and the operations will repeat. The AMR will be equipped with a cage and will drive to each handover location from where products must be picked for that order.

5.1.2 Zone based - Model 2

Since this model is based on the previous one, it has a very similar layout. It also has the same travel routes along with the shortcut paths and the additional return path at the top cross aisle. However, the need for a fast/overtaking lane in the middle cross aisle is no more a necessity in this setup and has been removed. The Figure 15 represents the layout of this model. The figure also displays the active pick locations in each zone for an order indicated by black boxes. AMRs are also shown, indicated by red rounded rectangles.

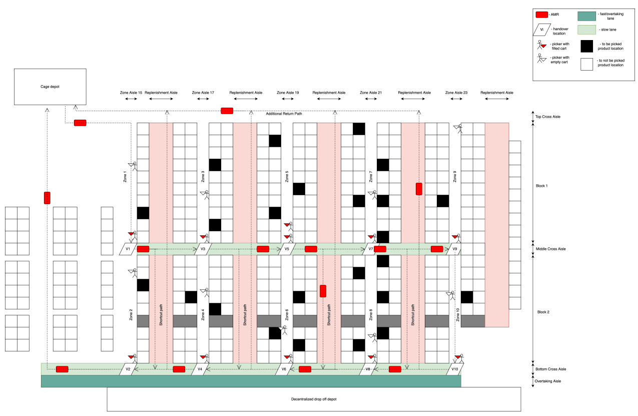

Fig. 15 Model 2 layout.

The significant change to this model is in the method of operations. Instead of having pickers pick products for a single order at a time, here, they would pick SKUs for the next 5 orders from their zone. Each zone would also have 2 pickers and be equipped with a picking cart which would have 5 mini-compartments to temporarily store the SKUs of the 5 orders in each compartment respectively.

This way, when an AMR reaches the handover location of the zone, a picker will not only be waiting there ready with the respective SKUs for that AMR's order but also for the next 4. Hence, there shall be no other component that adds up to the wait time of an AMR at a handover location than the time taken by the picker to pass the SKUs from the temporary cart to the main order cage attached onto the AMR.

During the time when the first picker is at the handover location and passing all the SKUs, of the 5 orders the picker picked, into the 5 AMRs' cages, the second picker would be picking his/her assigned SKUs for the next 5 orders after the ones of the first picker. Hence, by the time the first picker is done with passing all the SKUs and the 6th AMR reaches the handover location, the second picker would be ready to cater the 6th AMR as well as the 4 after it.

With this process repeating, having 2 pickers in a zone makes sure that there is never a wait time for AMRs at handover locations.

The AMR's operation remains the same as it was in the previous model - it will be equipped with a cage and assigned to one order at a time. It will drive to all the handover locations of the zones it has to pick SKUs from for its order. As explained earlier, due to having 2 pickers in a zone who pick SKUs of next 5 orders in one cycle, AMRs will not have to wait at handover locations for as long as they had to in the previous model. Due to this reason, the overtaking lane in the middle aisle has also been removed as queuing would be minimal in this setup.

5.1.3 Zone-based picking - Model 3

In this model that would use routes A and C for collection, the configurations become a bit different. The model's layout can be seen in Figure 16. In order to avoid solution symmetrical to previous one, collection will not be done on the way back and comeback route needs to be introduced. In this model there must be 1 zone per aisle and collection cages are loaded independently on each collection route, at both ends of each zone. As route B is not used the two blocks of shelves can be expanded by adding more shelves and products to the route B area. In **??** the figure **??** shows that two AMRs are able to move in independent lanes through route A. This way a comeback route can be placed next to collection route A.

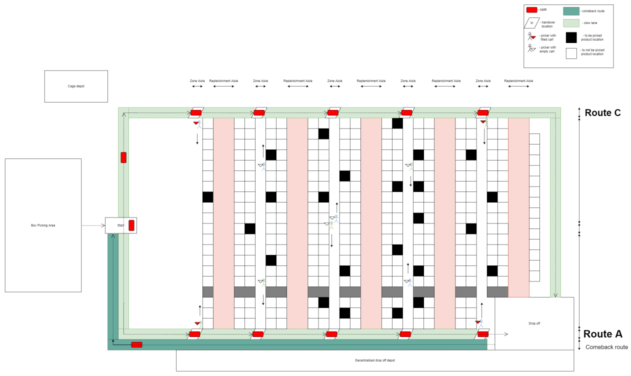

Fig. 16 Model 3 layout.

This zone-based model starts at the "start" point shown in the Figure 16. The logic of warehouse management system when creating new orders is the same as described in zone-based model 1. At start location the cages are collected and placed on the AMRs which will be distributed by the AMR cloud system to start the picking process in one of the two collection routes A and C. The goal will be an even distribution of AMRs in collection routes A and C. While moving trough the collection routes the AMRs will stop at the handover locations to drop-off the cage, which will be collected by the worker. After dropping-off the cage, it will collect the next cage from the worker that has kitted this cage with products and left it at zone border. The same operations will be happening at the other side of the zone, on opposite collection route.

The workers will move circularly through the zones, while collecting all of the needed products in their zone. They will continuously pick up the cage from one collection route, kit the products in the zone and drop it off to the AMR on the opposite collection route.

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References

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