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OPERATIONS AUTOMATIZATION AND DIGITALIZATION – A RESEARCH AND INNOVATION COLLABORATION IN PHYSICAL WAREHOUSING, IMPROVEMENT IDEAS IN AS/RS AND 3PL LOGISTICS CONTEXT

Case study Research report

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Forewords

This report is a result of collaboration work between LUT University and a leading logistics industry sector company, focusing on shared research and innovation efforts and pioneering in new products and services in their own business field. Authors would like to say our most humble thanks for Hub logistics for all the effort, time and data given for this research work and support for the research collaboration.

Special thanks for the CEO, Members of board, Sales and business unit leaders, automation maintenance team members, operational team leader and key account managers who all have been valuable and highly appreciated knowledge, idea and development innovation boosters in the collaborative analysis and case specific automation & digitalization related possibilities consideration discussions.

"Do what you feel in your heart to be right, for you'll be criticized anyway." ***Eleanor Roosevelt***

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Operations automatization and digitalization – a research and innovation collaboration in physical warehousing, improvement ideas in AS/RS and 3PL logistics context

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1. INTRODUCTION

This report continues university - industry collaboration innovation studies series within project collaboration in logistics operations digitalization and automatization context with the focus on digitally transforming the operations to be more efficient, effective and safe for the work force. This second report describes the main shared development effort with the company starting with general overview of Automated Storage and Retrieval Systems (AS/RS from now onwards) customers and ending to more detailed improvements of AS/RS operations, in the following topic fields:

- new and current customers' order patterns management
- known AS/RS practices in literature
- AS/RS shuttles and lifts analysis
- workforce and space distribution predictions
- picking and buffer totes operational issues
- picking robot and its installation suggestions
- conveyor belts improvements

This report is multipart research series into logistics research dat, analysis, development ideas and RDI points that has surfaces in this industry – university collaboration effort. For more about best collaboration practices in logistics context, we suggest reader to refer to publication (Salmela et al., 2011) and automating inventory levels adjustments based on dynamic algorithms (Happonen and Salmela, 2011a; Happonen and Salmela, 2011b; Happonen, 2012), Demand-Supply Synchronization (Salmela and Happonen, 2009a; Salmela et al., 2012) and finally for future seekers looking for high level asset management in fleet level (Kortelainen et al., 2016; Kinnunen et al., 2019).

The report contains ideas generated for higher utilization of current and future resources and to improve work models, following previous study in the series (Minashkina and Happonen, 2018). The work was basis to produce the investigation into digitalization and automatization as a tool for sustainability and to boost decarbonizing of warehousing activities (Minashkina and Happonen, 2019a) plus selecting WMS with sustainable considerations (Minashkina and Happonen, 2019b), which transform companies from traditional to knowledge companies (Kortelainen et al., 2019).

2. POTENTIAL NEW CUSTOMERS AND CUSTOMER RELATED IDEOLOGIES

This chapter start with data about the analysis of customer order patterns and how that might affect the way Hub logistics might want to develop their actions in operations and ways Hub logistics customers are served in the future. So as a part of this research project, it is decided that studying online customers' buying patterns should help Hub logistics to predict different scenarios for the Hakkila warehouse current and future customers behavior. Moreover, this chapter should give Hub logistics the idea what their customer might be and insights about understanding Business-to-Customers (B2C hereinafter) buying actions, what they want and how do they react to certain logistic options. Moreover, this knowledge can be used for further negotiating and cooperating with Hub logistics Business-to-Business (further in the text as B2B) clients whose customers are in B2C market. For example, according to statistics gathered most popular categories of goods purchased online are shown as follows in the Table 1 below with the corresponding values in the decreasing order given in the studies found:

Table 1. E-commerce goods popular categories.

	Finnish market study (KPMG 2017, 7)	US market study (Saleh 2017)	(Santos 2017)
Clothing/footwear	34%	63%	mentioned
Books	28%	67%	mentioned
Electronics	24%	69%	mentioned
Sport/fitness/leisure activities	11%	20%	mentioned
Food & Groceries	4%	20%	
Household good		38%	
Office suppliers		30%	
Pet suppliers		20%	
Health & beauty (perfumes, creams, cosmetics and etc.)	14%		mentioned
Car/boat/motorcycle	6%		
Childrens' articles & items (e.g. games, toys)	5%		mentioned
Furniture & décor			mentioned
Accessories			mentioned
Online Courses			mentioned
Customized products			mentioned
Subscription Clubs			mentioned

- Among the Nordic countries Finland scores the highest percent of returns of e-consumers (Postnord 2017a, 16), also clothing e-commerce goods experience

the highest return way traffic → this sort of customer group serving companies might not best customers for Hub logistics or at least the service fee for processing returns has to be considered really closely.

  - Also Hub logistics might want to consider an innovation workshops for both to the returns processing and Hub logistics work parts with the customer AND also shared workshops on how the end customers are given different incentives to not to order in a way that generates bigger amounts returns.

- Finnish e-commerce goods growing segments are DIY products (construction kits, fix-it-yourself home & garden furniture), clothing, electronics, sport and outdoor activities products (Postnord 2017a, 7).
  - Compared to earlier problem of big return rate, one could assume DIY product orders does not have that big of a problem in that department. In short, if you open up packet with DIY products and start building something, you cannot return the product in that point. With clothes, even when you have tested the product on you, you in general have the right to return it for full re-fund.
- In addition to online consumers behavior, people who spend more time on selecting a purchase want their purchase fast, because they have already spent enough time choosing it as it is shown on the Figure 1 below (KPMG 2017, 26).

Most impulsive categories	Percentage of purchases made same day
Food/groceries	51%
Beer	49%
Pharmacy/healthcare	46%
Wine	44%
Books/music	43%
Pet food and supplies	41%
Liquor	36%

Least impulsive categories	Percentage of purchases made same day
Telecommunications/phones	10%
Furniture/home decor	14%
Electronics/computers/peripherals	15%
Household goods and appliances	18%
Fine jewelry/watches	18%
Sporting goods/equipment	18%

Figure 1. Online consumer behavior for impulsive and nonspontaneous well-considered online goods purchases (KPMG 2017).

Related to the findings, what Hub logistics could do in future would be a possibility to think of working in closer cooperation together with companies whose products are stored in Hakkila warehouse. This would be done to avoid bottleneck scenarios (e.g. such as orders spikes) placing a customer order completion on another day (not same day as an order is registered). To be able to achieve this, Hub logistics would need to work

together with their B2B partners to offer different shipment price options for customer who would be willing to wait little bit more for deliveries, as based on research data:

- **Free delivery or discounted shipping privileges to customers** (94% of respondent survived in this study (Whistl Ltd. 2017) and discounted shipping (by 69% interviewees) (Saleh 2017) and **coupons for next purchase** (eMarketer Inc. 2016).
    - 80% of customers are more likely to purchase something online if it has free delivery (Saleh 2017).
    - 13% of customers in this study agree on that if they reach a certain quantity of goods ordered in their cart (Saleh 2017).
    - Meanwhile, study about Nordic countries show that online shopping drivers for customers here mostly are cost of delivery, time and ability to choose when a delivery performed (Postnord 2017b, 45).
- **Premium costs for fast delivery** there are situations when digital buyers are willing to pay more for faster delivery if they needed an item faster due to personal reasons, like birthdays (a half of respondents' votes) (eMarketer Inc. 2016).
    - There are examples of this sort of early test in Finland already. Basic models typically work in away, that customers do pay extra for same day delivery, and orders have to be made to only to items that are currently in stock, plus the order has to arrive to warehouse before a certain deadline (e.g. 10AM).
    - These models have had their challenges, but nevertheless one can clearly see from other studies, that consumers' willingness to pay extra has grown for fast and convenient delivery services.
- Weekend delivery practice for extra price:
    - *Saturday delivery* (35% of customers votes for this) is a great option to appeal to those customers who are out of the house during the week, but just 33% of all and 46% of shop retailers offer this (Charlton 2013).
    - *Sunday delivery* is popular only among 13 % due to high costs (Jindal 2016).
- The most popular adopted by UK retailers are offer **next day delivery** (65%) or **delivery for customers' convenient day** for them (20%, in other study that scored 8%), **click and collect** (57%) (Ecommerce News 2016).

- Another motivating factor for customers' is easy returns and exchanges (62%) (Saleh 2017).

So, when we are looking for new opportunities for fitting customers, Hub logistics might want to consider B2B customers who are able to serve their own customers with delayed deliveries. Customers who do not demand **immediately goods deliveries** would allow more efficient use of space and pickup process work hour's usage. There might be some example of this style of goods in a group of items that **people need in their free time** like on weekends. Particularly, examples could be items like leisure activities related things: gardening, barbeque, cooking, sports, non-immediate car & bicycle fixing work, home decorations and so on.

3. AS/RS RELATED LITERATURE ANALYSIS

The AS/RS material-handling equipment installed in Hub logistics Hakkila warehouse refer to mini-load system because of moving totes and not pallets (Rajković 2017). There is not that much information or evidences in literature about studied AS/RS bottlenecks in general. In one study of Ekren & Heragu (2010) it is said that lifts used in AS/RS are typically not the bottleneck in an AS/RS, but they have a significant influence on throughput capacity. Considering that, in a couple of studies AS/RS should have special treatment of high priority over low priority storage goods, apply storage location rules and storage policy strategy for efficient and effective performance (Potrč et al. 2004; Park et al. 2006; Rajković 2017). Roodbergen & Vis (2009, 349) propose another list of storage assignments for AS/RS settings which are:

- random
- dedicated
- based on stored items class/types
- based on items full-turnover
- closest open location

The recommendation for Hub logistics would be to discover Knapp AS/RS opportunities there. The Table 2 depicts some methods for storage in the AS/RS.

Table 2. Set of methods for AS/RS setting rules (adapted from Roodbergen & Vis (2009)).

AS/RS storage rules	Explanation of retrieval based on
First-come-first-completed	orders registration sequence
Shortest completion time	orders shortest completion time required
Nearest-neighbours	pairs of storage & retrieval request chosen in the minimum distance from the storage to retrieval location
On-line asymmetric	heuristics and an optimal branch and bound method to determine sequence for all known loads
Shortest leg	storage locations made before with the least extra travelling distance for retrieval

Gaku & Takakuwa (2017, 3181) in their research has such AS/RS setting that units with higher priority to be done are located near the AS/RS points for quick processing. Then,

in the study of Potrč et al. (2004) it is recommended in AS/RS to identify correlated products, namely, certain product types ordered together and store them together. Thus, traveling retrieval time can be reduced by 30-40%. These products can be defined from the historical data and usually are the ones from the same supplier, same size and colour. It is important for Hub logistics to know usually ordered correlated products in Hakkila such as phones and their cases. Since, it is matter for number of totes used for storing these items and later occupied place in the conveyor (one tote in the conveyor vs multiple totes at the same time), Furthermore, Hub logistics can discuss with Elisa possible future special offers like a S9 goes with a cover and put them in one tote to save retrieval time and tote conveyor place**.**

4. SPEED ANALYSIS FOR AS/RS SHUTTLES AND LIFTS

The Table 3 bellow gathers information about the Hub logistics warehouse.

Table 3. Information about Hakkila AS/RS.

HAKKILA AS/RS DESCRIPTION	VALUE
storage levels	4
shuttles in the 1st ground level	5
shuttles in the next 3 levels	6
total number of shuttles (*n)*	23

In order to predict the Hub logistics AS/RS performance from the theoretical point of view, the KPI formula for measuring the performance in maximum number of outgoing retrieving and incoming storing units per hour used from the study of Gaku & Takakuwa (2017). So, the formula to calculate wanted AS/RS performance *(I)* in 1 hour in milliseconds *(T)* is presented in the Figure 2.

$$I = T/max\left[\underbrace{2a+b+c}_{\text{expected time of one round-trip of a lifter}}, \frac{\overbrace{2(2x+y+z)}^{\text{expected time of one round-trip of a shuttle}}}{n}\right]$$

Figure 2. KPI for totes per hour calculation from Gaku & Takakuwa (2017).

To fill the formula with corresponding values, corresponding warehouse measurements were done. To start with the total amount of shuttles used in one section of AS/RS (n) equals 23 shown in the Table 4.

Table 4. Hakkila warehouse AS/RS information.

HAKKILA AS/RS DESCRIPTION	VALUE
storage levels	4
shuttles in the 1st ground level	5
shuttles in the next 3 levels	6
total number of shuttles (*n*)	23

While the Table 5 presents time measurement in milliseconds for AS/RS activities.

Table 5. Shuttle and lift time measurements.

TRANSPORTERS	ACTIVITY	TIME (ms)
SHUTTLE	a shuttle goes to the end	44380
	a shuttle returns back	35530
	a shuttle goes the end and back	80310
LIFTER	a lift goes down from the top	3350
	a lift goes from the top to down	5300

From these numbers the values for the formula (the Figure 2) can be calculated. The values for formula are in the Table 6 with their further description.

Table 6. A shuttle and lift traveling formula time measutements.

TRANSPORTERS	ACTIVITY	VALUE	TIME (ms)
SHUTTLE	One-way moving time from the base position to the halfway point	*a*	2162.5
	Loading time in a lifter	*b*	600
	Unlolading time from a lifter	*c*	600
LIFTER	One-way moving time from the base position to the halfway point	*x*	19977.5
	Loading time in a shuttle	*y*	6450
	Unloading time from a shuttle	*z*	6450

Thus, the maximum amounts of units (totes) storing and retrieving (S/R) for a lifter and shuttle in 1 hour (3600000 ms) are in the Table 7.

Table 7. Shuttle's and lift's totes maximum S/R in 1 hour.

TRANSPORTERS	UNITS S/R MAX AMOUNT
SHUTTLE	783
LIFTER	652

In other words, Hub logistics can see that either shuttles or lifts can become their bottlenecks if they are aiming at higher productivity results.

5. ANALYZING AS/RS & WORKFORCE ALLOCATIONS (NEW CUSTOMER CASE)

This chapter is based on close collaboration work with Hub logistics. It is a scenario analysis that focuses on simulating how the amount of outgoing material buffer is going to be filled up, compared to current situation (the current peak material amount is simulated to have level 100). By using, the current workloads and outgoing shipment amounts as basis for the reference numbering, Hub logistics can compare the man-hours needed now for the current operations to speculated future needs in different change cases. For example if the current clients need for Hub logistics to scale up the work done for them, or in case if there would be new clients or e.g. in a case of change in delivery and/or outgoing shipment times.

5.1. Resource usage analysis in decanting. New customer(s) servicing affect to resource allocation.

For baseline, a field situation in decanting was carried out. Also, a model with a representative of the case company was generated too. In this case, as the following timeline picture for 2 full days simulates, the first peak of input happens around 10 o'clock in the morning time. In that time patch of ingoing material flow arrives to warehouse and fills up part of the buffer space in decanting. It is assumed that the work force starts the decanting process, so the buffer is started to be used and material flows into AS/RS. Few hours later, roughly in midday rest of the trucks will have arrived in warehouse and the buffer for input is in maximum levels. As reference, with current layout (the autumn 2018) the reference number was allocated to 90 units. So now we are in midday, the morning shift is at work and does decanting work. Based on the discussions, it is assumed that the decanting continues around start of the early parts of evening time, in this case around 18:00 plus minutes 3 minutes or so. Basically, it is assumed that all priority decanting has been done and it is possible something is still in buffer, which will be taken care by the early morning shift starting in next day.

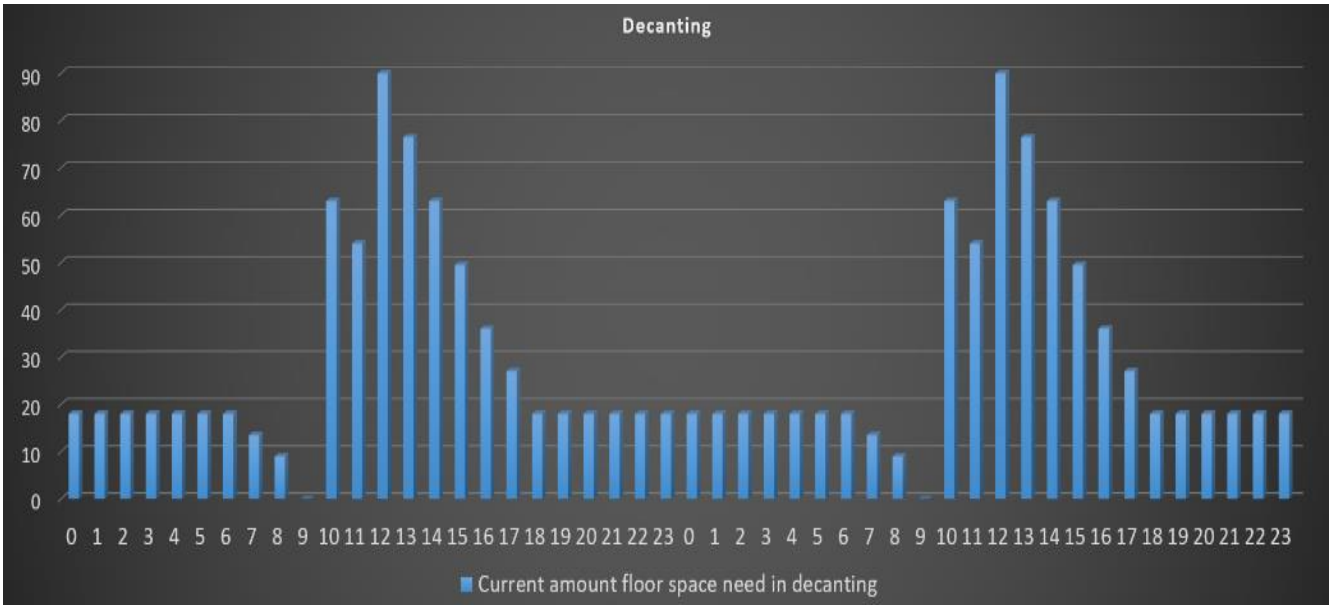


Figure 3. Current decanting buffer.

By looking at the Figure 3, the work of morning shift can be seen in the visualization as a level of the buffer going from 20 units amounts all the way to zero just before 9 o'clock in the morning. By design, this should keep the buffer quite clean and AS/RS should have almost all inventory in it at maximum delay of 1 day, in most cases the material is already inside AS/RS at the same time it arrives to warehouse. In the current situation, space is not an issue and material is stored to the automated warehouse process inside 3 to 6 hours' time period from truck arrival (depending on SLA).

In the next visualization in the Figure 4, a new customer profile with different work time, outbound traffic and delivery needs is added to this data as scenario to be analyzed. For this new customer, the inbound deliveries are assumed to arrive between 9:00 morning time and midday. The trucks come in as the road conditions allow, so for the sake of this simulations the flow is somewhat balanced between the time slot.

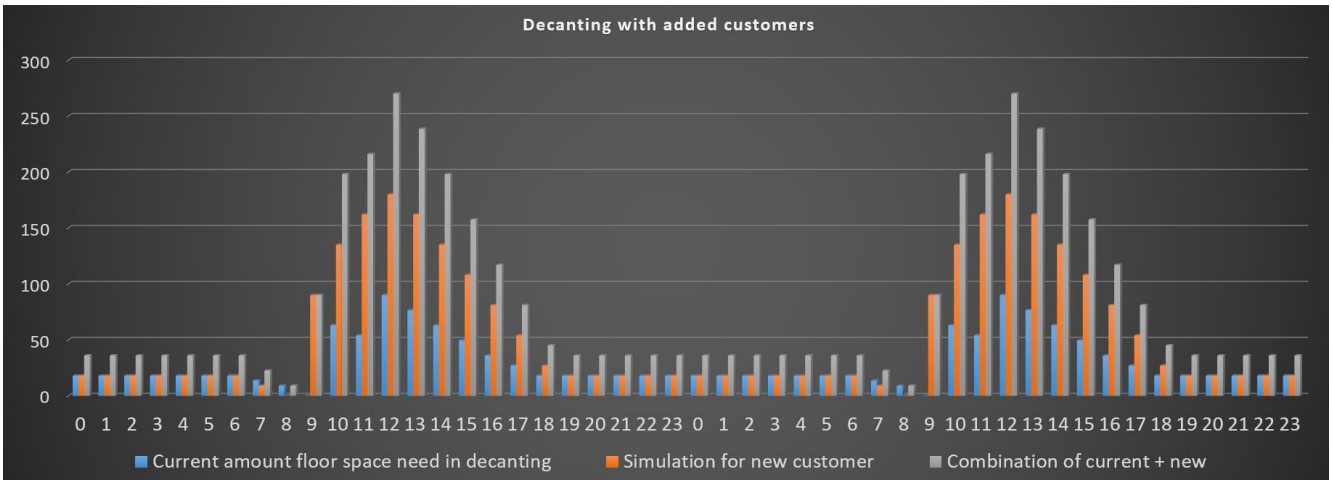


Figure 4. Current decanting buffer + new customer's buffer.

What can be seen from the visualization is the reality that this new customer or a combination of customers inbound needs will mean more floor space needed by Hub logistics for decanting buffer. The visualization is already based on assumption that these new customers will have additional team to work with this new input flow and additional decanting stations are used. Based on discussions with Hub logistics development team, the system input capacity or storage capacity will not be a problem, Also, as humans are not that fast on generating big flow of totes (units per minute), this part of growth should not be problem for Hakkila warehouse. For example, this scenario exercise does show that it might be possible for Hub logistics to end up to a situation that they would need 2.5x times the floor space for decanting buffer, compared the current situation. The current situation in the warehouse actually can take in more inbound traffic than what is now happening (with current layout) and a field research to surrounding spaces revealed near future changes that will clear up more space around decanting stations. All in all, we (Hub logistics presentative with us) did judge that with the given simulation parameters the situation is acceptable and AS/RS & 1st floor facilities and spaces available will handle this sort of growth.

5.2. Analysis for floor space resource needs after packing stations in case of new customer(s)

Given the results for the inbound floor space needs analyses, we changed the focus to look up the outbound traffic, workloads, space needs and so on. For this purpose, the first step was to analyze the current floor space usage with the current layout and pickup timetables on so on. This analyzes result is shown in the following visualization in the Figure 5.

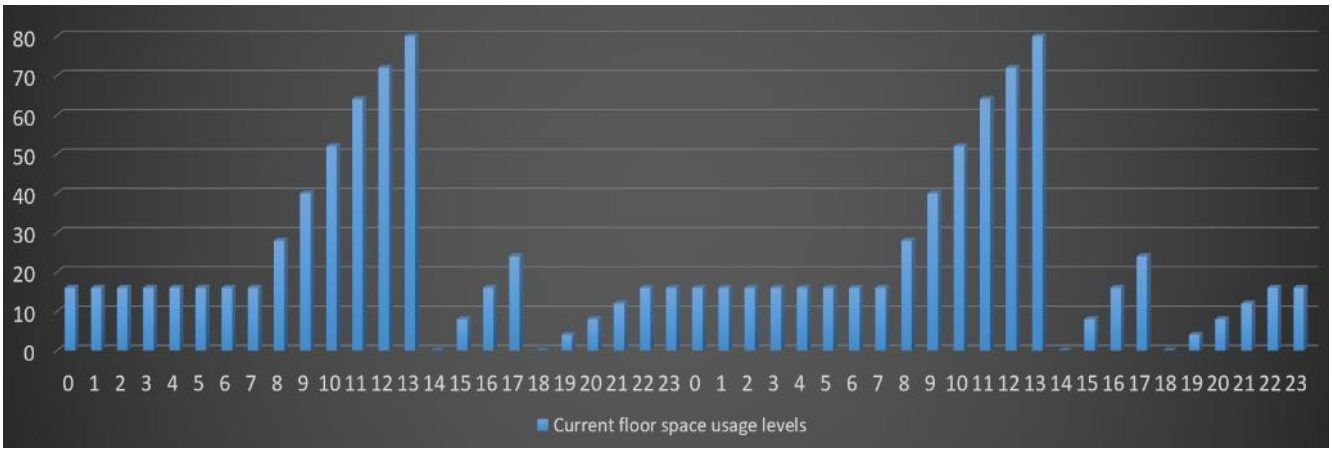


Figure 5. Current floor space utilization.

It is quite clear in this visualization that work starts roughly around 6 or 7 in morning time and the results of this work start to show up in floor space usage in hour or two later. This trend of growing of need for space goes up until 14 when first batch of trucks are already out with big part of that days outgoing flow. After that the pickup and packing up process continues to build new outgoing buffer that is picked up around 18 in late afternoon. After that some picking and packing is still done, and that is the work that builds up the outgoing buffer into outbound floor spaces, which will be reserved over the night too.

So that was the current setup, and as one can see already from the pictures, current peaks go almost as high as to range of 80 percent of space used currently available. The key for success would be try to either reorder the outgoing space layout radically, or try to use the times, which are now not that much utilized at all. The following scenario is partially doing both, basically by simulating a new demand from new customer(s) that would need night time picking. Their demand for AS/RS capacity will be higher that current use, but the trend pattern for daily resource demand in picking and packing would be different. All this is visualized in the following Figure 6.

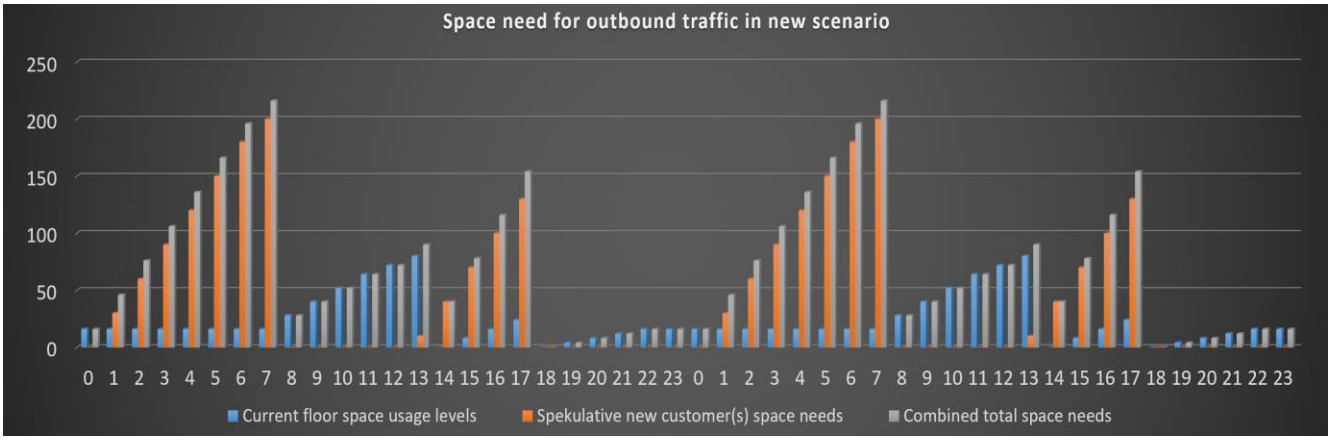


Figure 6. Current floor space utilization + new customer's operations.

Now in this scenario, one can see that the outbound space needed is in the same situation at midnight, as if it was previously. On another hand this is exactly, the time a night shift would start to work and as speculated earlier this new customer(s) combined demand would be more than the demand was previously. Now what this graph shows is the reality that a demand for floor space in outbound buffer spaces would be around 2X the current maximum. But the key aspect in hear is that this peak happens before 7 to 8 In morning. What it means is that the current floor space, which is used for inbound truck doors, could be reserved as outbound for the nighttime. When the morning comes, morning trucks come and clear up the night buffer and the floor is then clean for daytime inbound operations.

Now by looking up the daytime, one might also notice that there is some new additional work done between 13 up until 18 or so. However, here we are basically lucky, as current customer daytime first shipment patch has been collected out, and that means the outbound floor is once again ready to pick up new buffers. New buffers are built in afternoon time and the last trucks big those up and finally all is back in some minimal readymade buffer situation in middle of night. So, in short, we now have been looking the floor space for inbound and outbound floor space needs and in both situations, some small adjustments would be needed, but clearly, it is more than doable. But then, how about the amount of work force needed. Can people work in the different stations (are there enough stations compared the work needed to be done and so on). So, to take a look on that part of future predictions, we continued our modeling work into the labor force needs, related to people who work around the AS/RS related operations tasks.

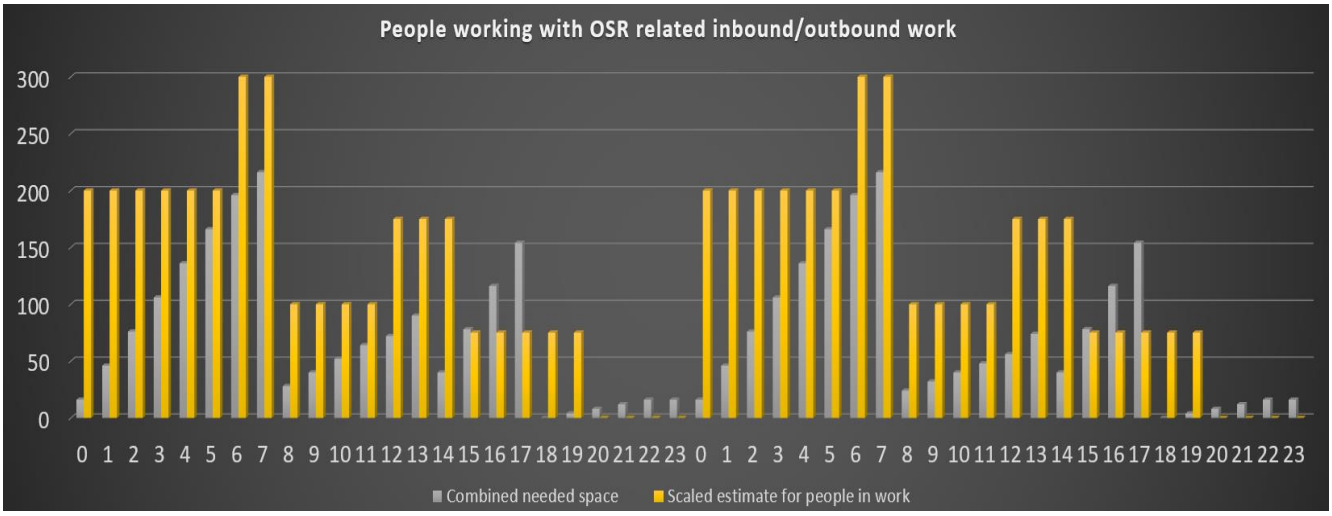


Figure 7. Combined estimated and needed floor space.

So, in this visualization in the Figure 7, we still present the combined estimate for needed floor space. This was done to show the reader how the amount of needed floor space is highly correlation to the number of labor force who works in those areas. More people highly correlates to more filled up floor space. To put it short, the new night shift would start around midnight (that is the shift that fills up the outbound floor space before the morning trucks do their pick up). The night shift and morning shift work side by side around an hour or two. This time is reserved for flexible work giving a possibility for Hub logistics to define picking and decanting work priorities depending on the work buffers, times of the truck pick up events and so on. Second parallel work time for current vs. predicted work force allocations would be in early afternoons, roughly in midday to 15:00 at afternoon or so. That is a second possibility for working some time for the flexible needs, before focusing on “business as usually”. All in all, it does seem that night shift with 2x labor force would not be a problem as currently people change from picking to packing and then back and stations are not full at all. So, they can continue doing switches, stations would just be more in full use. Also, in the most crowded times of the day, there would be decanting work to be done too and Hub logistics has additional space to build picking and packing station extensions. In short, by looking the people, stations and floor space, this sort of new customer(s) would seem to be a really good fit for Hub logistics Hakkila warehouses future to be seen.

6. ORDER PICKING TO AS/RS BUFFER. IMPROVING THE MORNING SHIFT EFFICIENCY.

As a part of the evaluation of current AS/RS related processes, a part conveyer line was found, that is not in use currently (it has a designed function connected to it when the system was built up, but that feature is not in use at the moment). The planned feature for this part of conveyor in Hakkila was to use it as route for ready picked totes to flow back to AS/RS for “safe keeping”. An example of customer case for directing already picked items back into AS/RS is e.g. the “later deliveries”. In this case a customer would be receiving an order in 5 days and this gives the warehouse workers multiple days buffer to pick this “priority 2” picking jobs. This on another hand would mean more efficient usage of picking stations as there would be a job buffer which to use in case of all priority 1 work is done before the work shift ends.

The conveyer part in discussion is located near the Error (Check) station. The location is circled with red color in the following Figure 8.

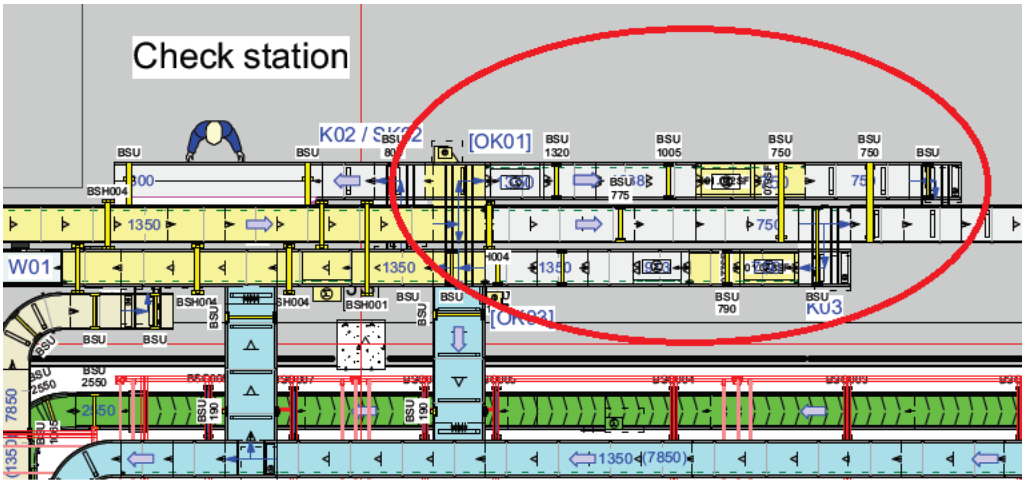


Figure 8. Sending back to AS/RSOSR part of the conveyor.

Based on observed system level data, provided by Hub logistics, one could see that the automation warehouse data shows usual daily processing time to end around 19:10 to 19:40 or so during work week days. To be sure, the system data was actually in line with reality, interviews with warehouse managers were used to confirm that this was the usual actual average ending time for the order-processed work. In fact, the latest time

an order was packed and ready for delivery was found to be around 19:40 on normal weekdays. The shift should continue up until 20:00, but because of the rule to not to leave any partly picked orders or source totes with content in them on the conveyors at the end of the day, workers do finish their shifts somewhat early every day. It is extremely hard to predict last patch of work total time needed to be completed, so the team leaders play it little bit safe, to at least not to go into overtime work. The base reason for this guideline of "no left overs in conveyer" comes from the safety and inventory balance keeping reason. To put it in other words, If something is not in live processing, it should be in the AS/RS. These regulations and safety principles results of the reality, that there aren't any partly picked orders in conveyers.

What this practice generates, is the reality that when the morning shift comes to work (for the picking and packing operations in 2nd floor), part of the team has to wait for work to be done. For example, for a four-people team, if 2 is assigned for picking, it means two will be waiting in packing stations for the system to start, to will up totes to picking stations and target totes to flow to packing stations. All this combined can add to 2*10 minutes of work time without work to do. In addition to that, It is well known fact that there is mostly all times big queue of orders to be picked soon, which means it is the worst time of the day to loose effective working time (e.g. remembering the SLA contracts and sanctions if the work is not happening in the speed agreed with the customers).

So taking the above mentioned in account, one could easily make a proposition for process enhancement. The 1st proposition would be some sort of process to do some order picking to buffer (either to AS/RS to in the line if there would customer items to allow that sort of arrangement). The 2nd proposition would be that packing personnel would start 20 minutes in decanting, giving the picking team a short time period to full fill the picking stations. The problem with the proposition is that is still shortens the time the whole morning shift is doing order processing in peak buffer time. The 3rd proposition would be to have one person to come in to morning shift around 20 minutes before the whole team. This person starts up the system and morning picking so the whole rest of the team comes to work into a situation that the whole picking and packing process is ready to go in the second they come to 2nd floor stations. In case some buffering would also being done to AS/RS in evening time, the time limit restriction for starting order inside last 20 minutes or so, could also be dropped off.

Figure 9. Totes' flows of the sending back to AS/RS OSR part of the conveyor.

So as combination of the proposition 1 and 3, the evening team would continue picking almost up until 20:00. There would be some buffer in AS/RS, a person for morning shift arrives 15 to 20 minutes earlier than everyone else and starts up everything in the system. When the rest of the morning team arrives, there is more than enough work for everyone to be done and the customer promises made in SLA (Service Level Agreement) will most likely be responded quite nicely, even in times of high order seasons. The Figure 9 above visualizes the route for totes to flow from picking stations to back into the AS/RS system for “over the night” buffer. The whole morning team can help up in the packing station preparations and starting of packing work, as AS/RS offers buffer work in the morning to help the team to “get into the speed”. After all morning preparations are ready, the team can split up to picking and packing tasks, however, is designed by the team leader.

7. ENHANCED OPERATIONS WITH PICKING ROBOT DEPLOYMENTS

The following chapter discusses the idea of installation in Hakkila warehouse a picking robot to facilitate warehouse operations weighting pros and cons of different option variants. Additionally some of the related selection parameters for the picking automation supporting robots will be discussed here too. Referring to area specific literature, Manzini (2012, 9) and Staudt et al. (2015, 5530) claim that there are a lot of automation going on in the warehouse order picking process, which can save 50% of warehouse picking labor in travelling time (Bonkenburg 2016, 23).

Moreover, with adding picking robot to already existing AS/RS warehouse operations can hold Hakkila warehouse to easily achieve 24/7 hours activity demanded from many warehouses today (Azadeh et al. 2017, 2; de Koster 2018, 38)

7.1. Picking robot options

Related to the idea of installing a picking robot, for example in the previous report in this topic called “Operations automatization and digitalization – a research and innovation collaboration in physical warehousing, AS/RS and 3PL logistics context” (Minashkina and Happonen, 2018), we propose building the U-turn curve for additional white totes buffer, as shown in the Figure 10 in the illustration presented below.

Figure 10. U-turn curve as a part of the conveyor for picking robot.

Building the conveyor part could be also one new pragmatic step towards building the automated picking robot in its assigned place (the red circle), as that was part of the original Hakkila warehouse 2nd floor development plan (visualized below in the Figure 11).

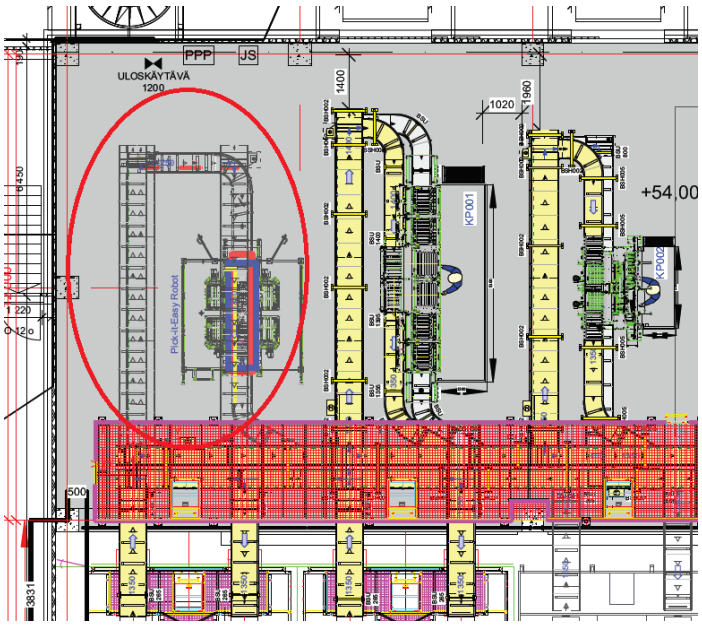


Figure 11. The future possible picking robot place from Hakkila warehouse.

Based on our discussions, it seems that for Hub logistics, one of the most interesting option is most probable to build an arm-based robot solution that would be picking products from totes one by one. Given the impression, in following a short list of

selection of different picking robots will be presented and discussed shortly. The pictures also include hyperlinks to presentation videos to see the robots in action.

- **DEMATIC** robot - picking good to robot from conveyor (the Figure 12). This robot seems to rely on bar codes in the items that will be picked from the source totes. Given the relatively small size of bar codes e.g. in mobile phone packets and the fact that there are multiple codes in one packet, there could be some limitations to apply this sort of robotic picking solution into use in Hub logistics warehouse. Also, similar limitation might apply to following KNAPP based solution too (video)

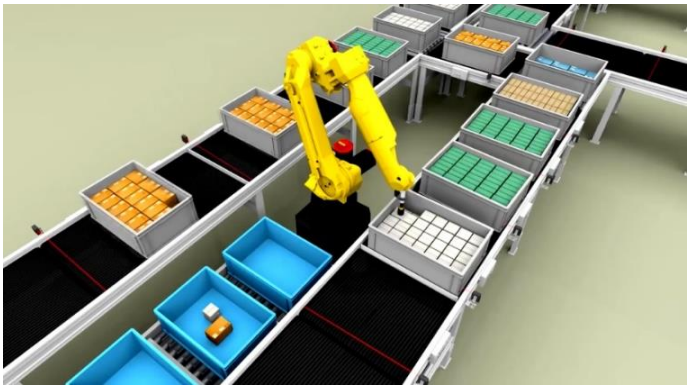


Figure 12. DEMATIC picking robot.

- **KNAPP Pick-it-Easy robot.** This robot from KNAPP should offer one of the smoothest integrations with current Hub logistics AS/RS related aspects, that have currently AS/RS KNAPP automated warehouse core components (the Figure 13). In addition to ease of integration, this robot is able to pick and put articles from source totes to target totes which actually simulates the work human pickers do in current picking stations. This sort of robot could to "night shift picking by its own, basically meaning it would do picking into buffer inside the AS/RS and by doing so allowing next shift to start directly from ready picked buffer. The robot used replaceable jet nozzle suction-based solutions for different type of goods for different lifting actions, which allows it to be versatile. One thing that is not mentioned in the material is robot training. Given the huge amount of items stored in Hub logistics warehouses, the training cost per item needs to be considered as a part of important parameters related to robot picking options (video1, video2).

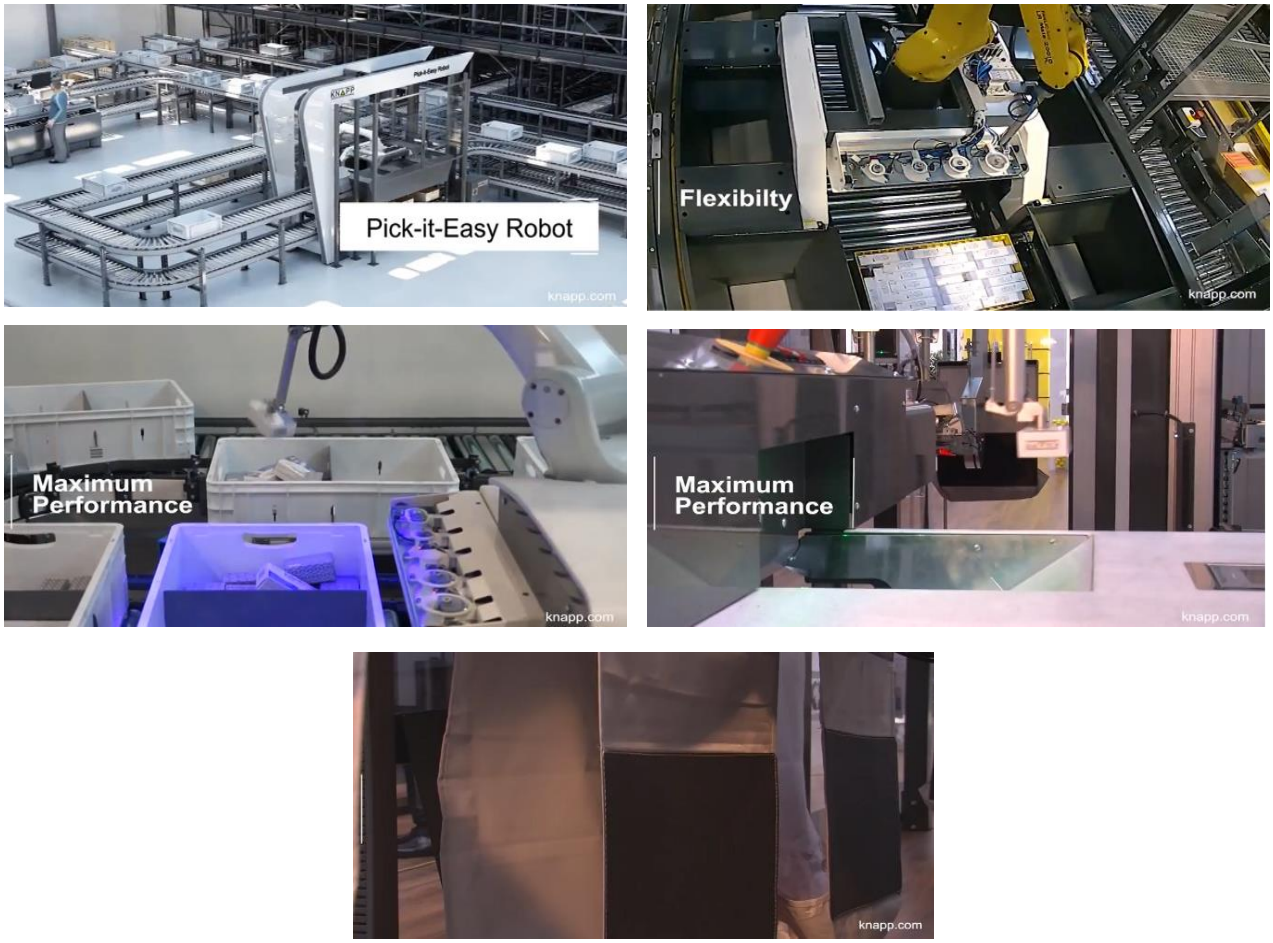
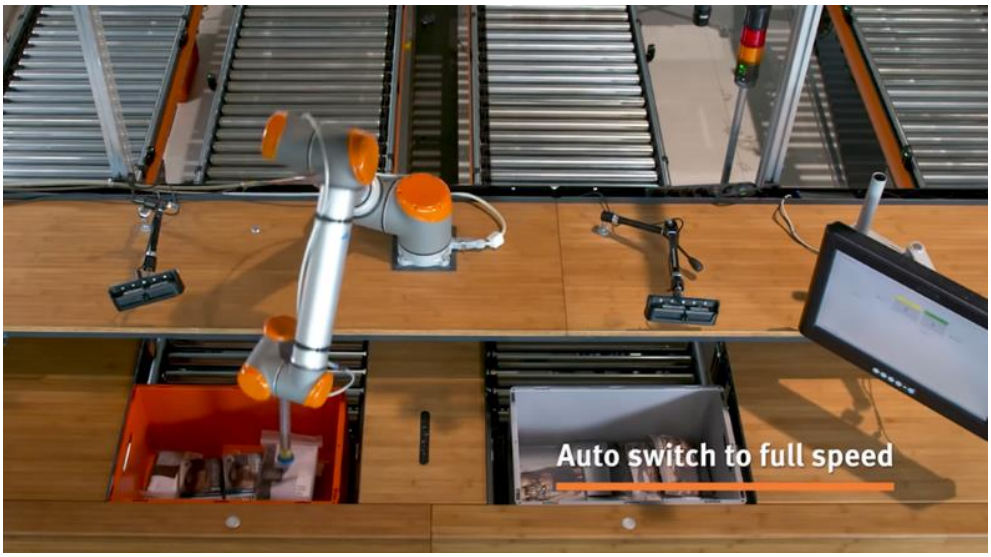


Figure 13. KNAPP Pick-it-Easy robot.

- **VANDERLANDE - Smart Item Robotics.** This robot video (video) present system capability for target tote product stacking and positioning modeling (the Figure 14). Given the earlier videos, other systems seem to have similar capabilities, but others do not promote it as clearly in their public material. That might indicate some competitive advantage Vanderland has been able to build into their offering. Whatever the reality, the current situation in Hub logistics process does seem to allow to not to put too much weight for this option, unless other robot systems would be so raff handling with the packets they pick, that it could show up in the items after picking (internal and/or external damage). In short at least a practical demonstration for robot selection needs to be acquired with the typical challenging items Hub logistics would need to pick with their robot for their current and future customers.

Figure 14. VANDERLANDE - Smart Item Robotics.



- **SWISSLOG LOGISTIC AUTOMATION ItemPiQ: Robot based solution.** Swisslog key promoting point is the minimal training the robot needs for starting its work (video). System uses KUKA robots for picking, which are capable of working near by human pickers. They also give a statement their system would be "easily integrated to other goods-to-person systems, but they do not give more specifics on promo material for that (the Figure 15).

Figure 15. SWISSLOG LOGISTIC AUTOMATION picking robot.

- **OCADO TECHNOLOGY** picking robot for mixed totes inventory (the **Error! Reference source not found.**). Designed for grocery store items. Uses artificial intelligence and computer vision to "understand" what it sees in the source box. Picking is based to suction cup and arm based solution (seems like this one does not allow easy picking head changes). One thing to point out is the idea of picking the items "in angle". Depending on items needed to be picked up, that sort of special aspect in picking robots capabilities might be important to consider (video)

Figure 16. OCADO TECHNOLOGY picking robot.

- **Amazon New Robo-Picker** for mixed SKUs (the Figure 17). Based on MIT technology review article, this robot "only needs to see seven images of a new object before it can reliably spot and grab it.", as mentioned earlier the training cost is something to take care to check out before making robot investments. This one at least gives clear benchmark in number level. On another hand, one thing that seems to be quite typical for robot picking is that they do not apply smooth accelerations and decelerations in picking head movements. For "smooth us butter" –picking this sort of mechanical capabilities should be considered too (one does not want to drop 1000 euros phone packet "on the fly") (video).

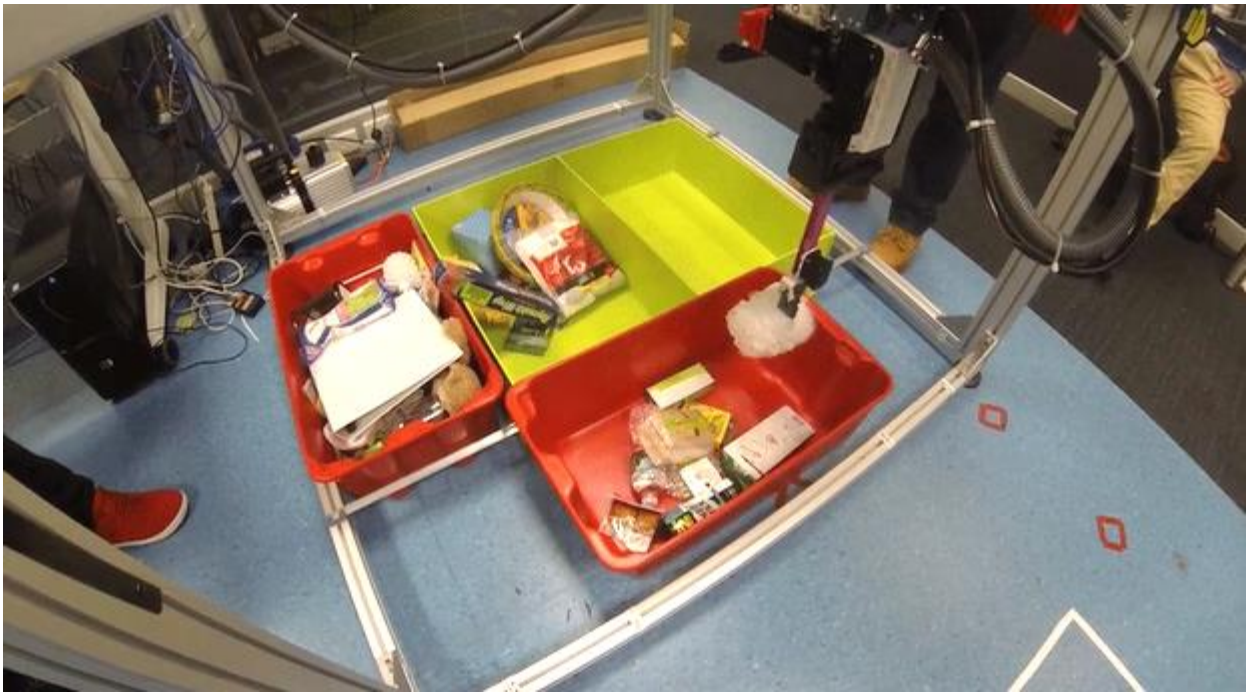


Figure 17. Amazon New Robo-Picker.

7.2. Summary of parameters / practical points for proper picking robot (implementation)

The following Table 8 is a short collection of different points Hub logistics would most definitely to think about in robot and/or system capabilities before making any investment decisions. These parameters are based on study made to robot types, named to be interesting by Hub logistics. Financial aspects as investment cost in start, integration costs and up keep costs are not listed, as those seem to be obvious for the case company to consider anyways.

Table 8. Picking robot parameters to consider.

Parameter	Explanation
Item identification model for items in source tote	Does the robot need to read e.g. bar codes? Is that possible if there are multiple codes in one packet? How about if the codes are in small print? How a robot will read IMEA of e.g. phone?
Item picking	Can robot handle soft packets, odd shape packets, packets in strange order inside the source tote and so on? How will it guarantee stability of picking?

	What is the picking/working distance for a robot?
Efforts to train the robot to work with any new item	How adaptive the robot is in the training process? Can supplier change the item / packet dimensions a little bit? Can robot even self-train itself to new items? Can robot pick from a tote that has multiple different items in their own slots? How about if the items are mixed mess inside one tote? How does a robot deal with errors? e.g. 3 iPhones ordered, but only 1 in the box?
Integration	What systems are familiar for the robot offering company? What sort of API interfaces are de facto standards openly available from the robot manufacturer? Can software robotics imitate human user within the automated system which does not know this new robot type?
Weight limitations	Can robot handle the heavy stuff too? Does the weight limitation vary with picking distance?
Item handling	Is the handling process itself smooth enough? Can robot do “soft touch” if needed?
Human safety	Can robot work nearby humans without protective “box”? How sensitive robot is for interruptions, human “in the way of work” and for the items it handless (drop a item to box are handle with care?)
Friendliness of user interfaces	In case of user interface for human operator to help the robot to solve a problem that has occurred in picking, how easy those are to work with? Different problem situations can be plentiful, it would be really important to map how robot can handle (“fix”) the problems. For example, if robot has problem of understanding stuff in source box, can it cancel that

	picking order and proceed to next one, or doe the process stop? What is interface language supported?
Picking angles	Does robot support special picking angles? Can it do optimized picking for improved speed based on routes the picking head needs to move between picks?
Smooth movements	Does robot support soft acceleration and decelerations? Can speed vs. smoothness be selected by the user of the robots, or is it fixed value?
Sustainability	How much energy does a robot consume (efficiency)? Any emission output to consider?
Maintenance	Can we talk one of your current customers directly? What is the maintenance cycle? When a robot should be calibrated? Can Hub logistics do so? Or only owner company does repairmen? What is expected life cycle (usable age)
People trainings	How a warehouse worker should deal with occurred problems in/with picking robot? How to release the work?

8. FASTER 90 DEGREES TOTE TURNS IN CONVEYORS

As a last part of this study, AS/RS conveyer line belt systems speed improvements were shortly investigated from efficiency improvement point of view. The study was done to find new ideas for time savings and item movement. Also these options for speed improvements were collected to give the logistics operator options to ask direct questions from the automation system providers to see would it be actually possible to try to speed up the connection points. Specially in the areas where conveyers cross over each other and where the input – output conveyer lines had to stop to wait a tote to change a direction.

1. A Modular conveyor belt that makes 90-degree transfers (M5482 roller-top belt for 90-degree transfers) shown in the Figure 18.
    a. http://www.packagingdigest.com/conveyors/modular-conveyor-belt-makes-90-degree-transfers140918

Figure 18. 90-degree belt conveyor.

2. A system that seem to be “Instant flow” 90 degree bent. The provider of the solution still not clear (figure 19).

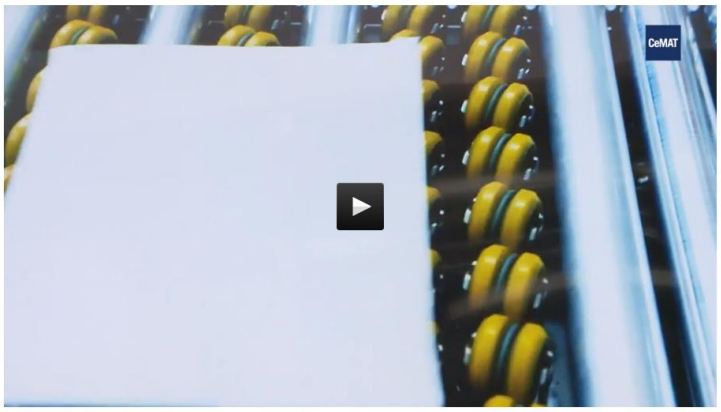


Figure 19. Flow of totes in 90-degree belt conveyor.

3. LVP Conveyors solution (Figure 20) for multiple direction sorting turn with “flow like” packet movement. The unit provides an ability to do sorting to 3 different locations and it is using a switch sorter for it’s actions.

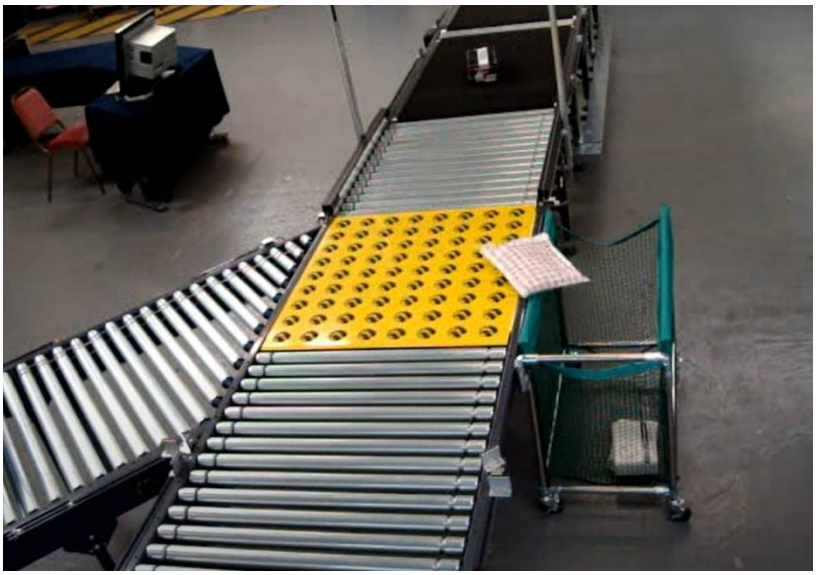


Figure 20. LVP Conveyors sorting solution (Video)

4. Similar to the previous one, a high-speed switch sorter (using roller conveyor ideology), from Conveyor Systems Ltd (Figure 21). This unit is pneumatically operated and able to divert products to multiple output lanes.

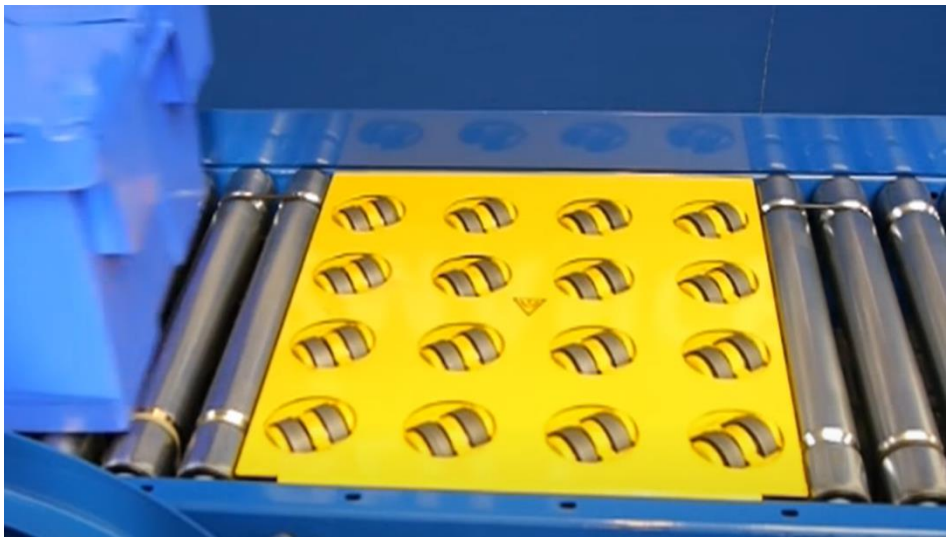


Figure 21. From Conveyor Systems Limited a high speed switch unit (Video)

5. Specialized solution from Avancon (Figure 22). A modular unit for building omni-directional transfer tables. The system uses the basic principle of roller conveyors, which can do crossings, work as diverters and also as sorters.

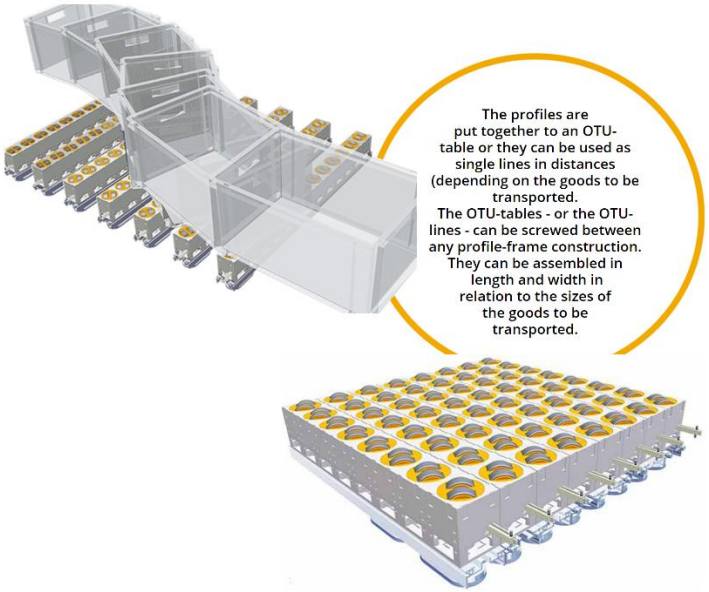


Figure 22. The avancon conveyor design (Videos)

6. Cellumation GmbH delivers celluveyor branded (figure 23) extra ordinary block (lego) like modular solution. Manufacturer calls these as cells, where one cell consists of a hexagonal unit with omnidirectional wheels and an intelligent control system. When building the unit, these cells can simply be clicked together. This special design feature gives logistics operators to fit the units for their special warehousing needs and to build the switching table to any shape and size. The single wheel steering technology will also allow the table to convey objects freely in all directions and orientations.

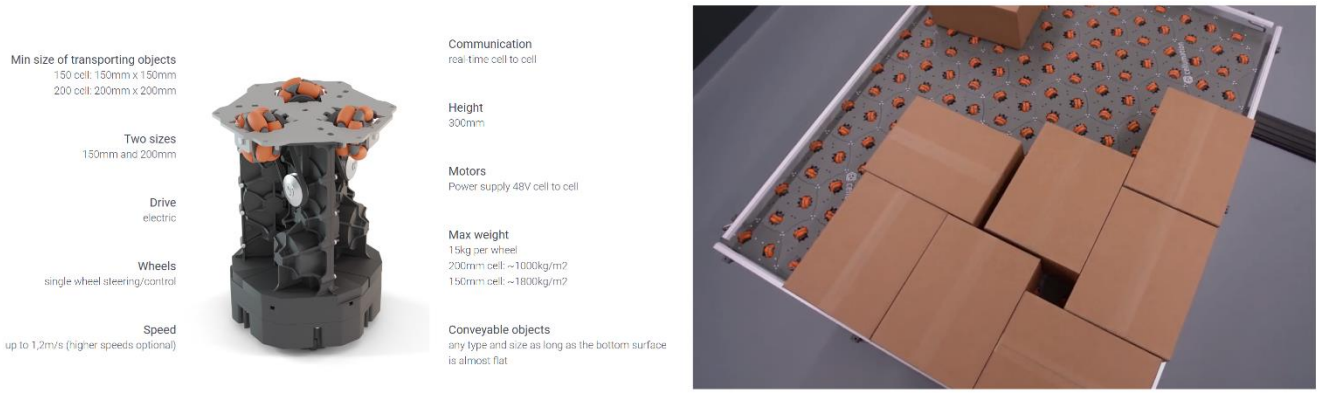


Figure 23. Innovative and flexibility & modular solution from cellumation GmbH (details, Video)

7. Omni Metalcraft Corp multi operational fast speed conveyer with integrated rollers. 11 Different operations including: Bumpturns, Aligners, Passive 90° Transfer Utilizing and End Stop, Switching, Layer and Row Forming, Singulation and Single Zone Sortation (figure 24).

Figure 24. Multi action roller belt conveyor from Omni Metalcraft Corp (Video)

9. CONCLUSION

This research project collaborative RDI work has been done in close cooperation with a well-known and fast grown 3PL operator. This Finnish based company has given the researchers an access to their daily operations, improvement strategies and shared their time to be part of analytical studies in their operations to enhance innovation and digitalization related research projects. Specially in innovation side, the studies focused in future opportunities, based on new development directions in technology, B2B customer demand and expectation models and customer (B2C markets) behavior changes in last few years (for example the buying behavior of consumer electronics and other goods people nowadays buy from internet).

Given the mentioned background this report points out findings and suggestions how a logistics operator might end up using this sort of information and changes in markets as a basis for them to enhance their services for their customers. Overall it is important to think what service providers can do for their customers and what is their natural service providing role (Salmela and Happonen, 2009b). For example, how service provider can and will manage customers' orders, deliveries related to outgoing orders and even the daily operations in unloading and packing of outgoing goods in automated warehouse environment to offer ever more efficient and faster services for their clients.

The report has looked up options to enhance the work done by the human operators, the options to speed up automated storage and retrieval machinery (AS/RS system) and also this research work has considered new picking robot options and the robot installation parameters too. In dynamic conveyer and goods flow side, a short review was done to continuous flow 90-degree special conveyer solutions for possibility to improve tote speeds and smoothen up their movements.

As final note, we would express our most humble gratitude for this research opportunity for Hub logistics. It has been understanding that the collaboration has been exceptionally open in knowledge sharing and level of discussions deepness. This sort of future looking thinking and readiness and openness for new ideas and outside views and opinions shows the readiness of the company to steer their ways of working, to support positive growth and wellbeing of their workforce.

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