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STUDY ON THE OPTIMISATION OF MATERIAL FLOWS WITHIN AN AUTOMATED WAREHOUSE EQUIPPED WITH AMRs

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Abstract: *The article presents the method of optimising flow within the distribution warehouse as well as the equipment needed to carry out this process. It is also intended to optimise the picking process through the optimal functioning of the existing AMRs in the warehouse as well as the packaging flow of the final order so that the entire activity has time, cost, flexibility and, finally, integration. The article consists of a presentation of the entire warehouse management, ways of optimising flows and last but not least, a presentation of the simulation of optimised equipment. On the other hand, it also aims to improve the process of packing the final order after the items arrive from picking. For this process, calculations are made involving the productivity of the entire process and the entire flow.*

Key words: *AMR, automation, RFID, cod QR, logistic flow, distribution warehouse, automated equipment, products.*

1. INTRODUCTION

The optimisation of material flows within warehouses is an essential aspect for increasing productivity and lowering the expenses associated with managing inventory within the warehouse. Therefore, conducting an in-depth analysis of the logistics flow of a product, starting from its reception in the warehouse until the order is completed, is necessary, as well as its optimisation to increase productivity (Fig. 1) [1].

In addition, in the design and organisation of a distribution warehouse, it must be considered that the various basic operations and processes necessary to fulfil the purpose they were created must be carried out in a logical chronology in space and time. The warehouse must be organised so that the two flows (the storage flow, consisting of reception and warehousing, and the sales flow, consisting of the delivery of goods) do not overlap.

The flow of an order represents its journey from the moment it is placed on the website until it is packed and ready for delivery (Fig. 2). Thus, each item in the order goes through the main steps required to complete the order, namely receiving the items ordered, picking them, dispatching the products, sorting, packing, and validating the final order.

The distribution warehouse must be organised so that the two flows (the warehousing flow, consisting of reception and storage, and the sales flow, consisting of the delivery of goods) do not overlap [2].

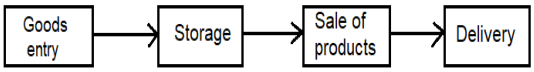

Fig. 1. The flow of a product through the warehouse.

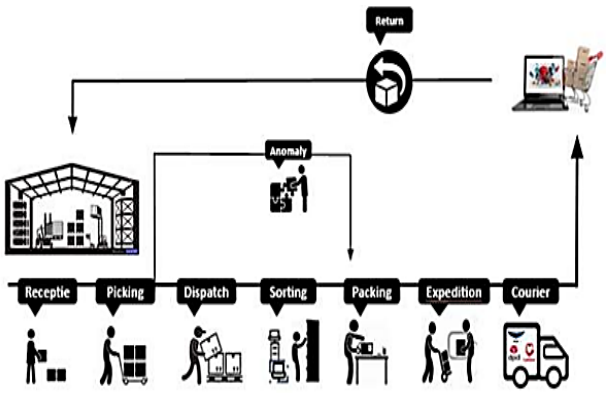

Fig. 2. The flow of an order from the moment it is placed on the website until it is completed.

The warehouse management system illustrates the activities carried out in the warehouse from the first operation of receiving the merchandise to the last operation of delivering processed orders (Fig. 3). Receiving merchandise in the warehouse, handling it, monitoring and processing all invoices, and, finally yet importantly, delivering the final orders are essential steps in a distribution warehouse [3].

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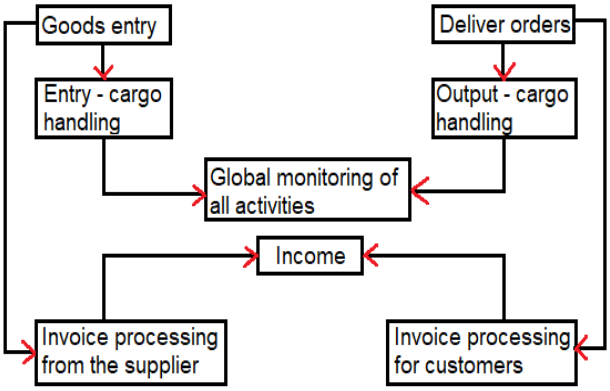

Fig. 3. Warehouse management system.

The space allocated to the distribution warehouse can also be optimised by storing goods according to their properties of use: allocating isolated spaces for goods with particular properties (temperature, humidity), providing storage racks with the main functions that the warehouse performs, and ensuring the circulation of all goods stored in the warehouse [4].

1.1. IT preparation of the orders from the distribution warehouse

Several steps take place in the warehouse to prepare the orders received from the customer so that each order is prepared correctly, contains all the required items, and, finally, the preparation time corresponds to the time allocated for this activity (Fig. 4).

All orders in the warehouse are prepared and stored for a certain period on pallets of various sizes by taking into consideration the size of the packed products and how they are handled (Fig. 5). In most cases, Euro pallets, industrial pallets, and half pallets with dimensions of 600 × 800 mm or 600 × 1000 mm are used.

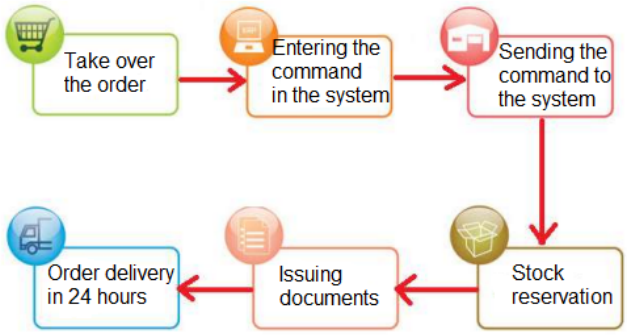

Fig. 4. All the operations required to complete an order.

Fig. 5. Pallet flow in a warehouse.

The purpose of using pallets for product storage:

- Creating palletised unit loads;
- More efficient use of warehouses;
- Protection of goods;
- Reduced costs of storage, loading and possible material damage.

In addition, the arrangement of the products on the pallet is a significant factor in palletising the products, thus creating the stack on the pallet. Therefore, by arranging the boxes in a column-like manner on the pallet, the most efficient solution is obtained for maintaining their durability (compactness) throughout transport and protecting the goods against compression. If goods on pallets do not provide a stable top surface, they expose the goods to damages and repackaging or delays in delivery [4].

1.2. Main functional areas within the distribution warehouse

All handling activities of materials stored within the warehouse are an integral concern of the entire unit. As a result, the following activities can be distinguished: reception of goods, storage, order picking, order preparation, sorting and transport of products.

This paper will highlight the operation of a warehouse using the FIFO method. In the distribution warehouse, products are collected from different suppliers and delivered to a number of customers. Thus, the distribution warehouse receives certain products from suppliers, unloads them in the warehouse, stores the items, receives orders from customers, fulfils orders received, prepares, and ships them to customers [5].

Figure 6 highlights three flows that contribute to warehouse management, namely:

Flow 1 refers to a model that describes a typical warehousing operation. Items are temporarily stored in an intermediate area, and orders are picked according to their priority. Only items that remain for long periods are typically designated for this intermediate area.

Flow 2 refers to items initially stored in the staging area and later transferred to the delivery area.

Flow 3 refers to items instantly sent to the picking area.

The following stages represent the main flow of products stored in the warehouse:

- The storage of the finished product before it is distributed to the end customer is a crucial element for the end customer. The deadline is considered critical, and the product specifications must be fully respected;

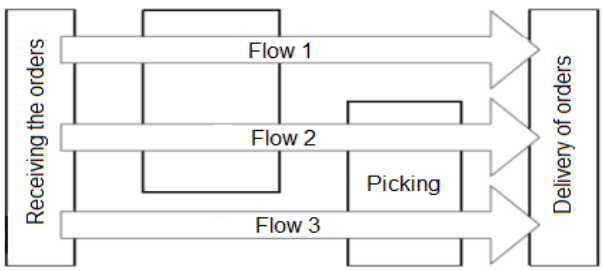

Fig. 6. Highlighting the main areas within the distribution warehouse.

- The services provided to customers must consider the product's quality, accuracy and durability.

2. EQUIPMENT AND SOFTWARE APPLICATIONS USED IN DISTRIBUTION WAREHOUSES

As stated above, the essential tasks in the warehouse consist of receiving goods, checking and storing products, preparing orders, packing goods and delivering them to the customer. Therefore, in order to optimise the space within the warehouse, it is desired:

- Automation of operations included in warehouse flows;
- Optimisation of internal transport;
- Determining how to store;
- Reduce warehouse errors and order picking time. By analysing the activity within a warehouse, it is found that the distribution warehouse stands out for its ability to store various types of products for a limited period (Fig. 7). This type of warehouse is assigned the following main functions: reception, quality and quantity checking of goods, storage, order picking, and dispatch [4].

This article looks at optimising space in a distribution warehouse. The process comprises several steps, starting with the pallet transfer equipment. The next step is to transfer the palletised goods from the unloading ramp to the reception area, where their quantitative and qualitative reception is carried out. Subsequently, the palletised goods are transferred from the receiving area to the storage area, considering the pallet stack's height and each product's specific storage requirements.

The activity continues with storing products in dedicated areas, order fulfilment, and transfer of prepared orders and their grouping on transport routes. Finally, the pallets are transferred to the dispatch ramp area and loaded onto the means of transport by car, culminating in the delivery of the orders.

2.1. The main equipment used in an automated warehouse

The main equipment used in an automated warehouse includes automated warehouse systems with shuttle pallets, conveyors, and automated guided vehicles (AGVs) or autonomous mobile robots (AMRs).

- **Pallet Shuttle** is an automated warehousing and recovery system composed of a small, automated cart and multi-level channel storage racks, each equipped with rails for movement (Fig. 8).

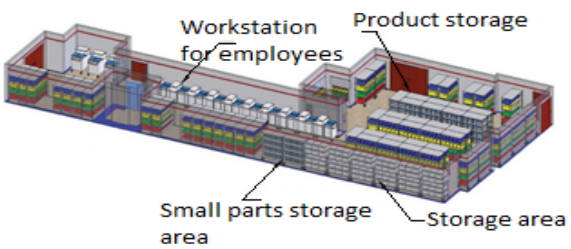

Fig. 7. Distribution centre, including all its key sectors.

Fig. 8. Pallet Shuttle.

The device's operating system is simple and efficient. When entering the shelf, the platform picks up a pallet and automatically moves it along the shelf until it reaches the end or until it identifies a free place to store it. At that point, it carefully positions the pallet on the shelf and then moves back to the shelf entrance to pick up the next pallet [5].

Advantages:

- Compact storage from shelf entry and exit;
- Inventory function – the system counts the pallets within the rack;
- Automatic storage and retrieval of any pallet on the shelf;
- Pallet storage and retrieval speeds between 0.92 and 1.1 m/s;
- It has precise parameterisation.

- **AMRs** in a warehouse are used to transfer pallets of goods to their storage area next to the existing shelves in the warehouse (Fig. 9). With the help of software, AMRs are made aware of the activities they have to perform, orient themselves in the warehouse and avoid collisions between each other and with other static objects. AMRs can also be used for moving pallets or even for picking operations. Some of these automated vehicles can move racks of products for picking.

AMRs also help prepare orders and position them where they are to be delivered. For example, if an order is received in the warehouse towards the end of the program and it needs to be delivered on a particular day, AMRs can quickly process the order. This ensures timely delivery and avoids problems with the end customer in the warehouse.

Fig. 9. Example of AMRs.

Fig. 10. Conveyors.

Fig. 11. Forklift.

- **Belt conveyors and roller conveyors** are transport equipment consisting of a frame in which rollers are mounted to support or transport goods packed or installed in containers or on standard pallets (euro pallets) or transport pallets for each application (Fig 10) [5].
- **The stacker** crane carries out the pallet transfer activity within the warehouse. Because it can transfer loads of up to 3 tons, some products in the warehouse are difficult to handle, which leads to an optimisation of the realisation time of the transfer activity of products, which follow to be stored.

In a distribution warehouse that is not automated, the forklift increases productivity, speeds up the process of transferring products, reduces errors, allows flexibility in performing operations, and, last but not least, reduces transfer times of palletised products (Fig. 11) [5].

2.2. Warehouse management software application

The digitisation of warehouse systems relies on automation, linking processes within an integrated system comprising equipment, machinery, personnel, and mobile devices. These components can communicate seamlessly, both within and outside the warehouse environment.

Optimisation of all steps in the warehouse is achieved thanks to a software system that reduces costs and the time when the order is picked. At the same time, it significantly increases efficiency, quality and profit.

Deploying a comprehensive warehouse management system tailored to current requirements stands as a pivotal step towards streamlining and optimising all operational processes.

Consequently, the main steps required to automate a warehouse are:

- Digitisation facilitates real-time access to data, enabling swift digitisation and transmission of information through the software solution;

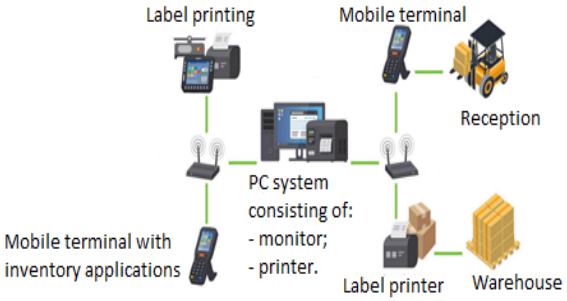

Fig. 12. Mode of operation of a WMS in the distribution warehouse.

- Mobility – allows all operators to be connected to the warehouse IT systems;
- Automation – organises warehouse processes by interconnecting equipment.

To achieve optimal warehouse results, it is essential to implement a Warehouse Management System (WMS) (Fig. 12). It provides inventory visibility and efficiently manages supply chain operations. Such software allows for fast order fulfilment. In addition, it extends supply chains to synchronise inventory management and order fulfilment processes while providing real-time visibility into the entire inventory [6].

The WMS is designed to automate and control operations in a warehouse so that the receiving, storage, and delivery process is continuous, fast, efficient, and error-free. Interfaced with barcode scanners and industrial tablets, the system simplifies the collection and recording of data about daily warehouse processes, providing access to information about stock and product movements.

The entire warehouse activity features time, cost, flexibility, and integration by automating all processes.

The WMS is a crucial supply chain element responsible for overseeing the movement of goods within the warehouse. WMS solutions are tailored to automate and enhance processes such as receiving, storage, picking, and shipping goods, offering real-time updates on inventory status and available storage capacity.

The benefits of the WMS system in the warehouse are:

- Business efficiency by centralising supply operations.
- Stock optimisation.
- Increased order fulfilment.
- Provides real-time information on the stock of goods.
- Increases the accuracy of the picking process.

The WMS system can integrate all the company's management functions, starting with planning activities, ensuring the stock of raw materials and materials, and last but not least, the financial and accounting management of stocks. It is software designed to make the management of goods in the warehouse easier, from their reception to delivery (Fig. 13). Based on multiple functionalities, a WMS system eliminates repetitive manual activities. This is achieved by optimising space and automating processes in the warehouse, which is an important component of the supply chain.

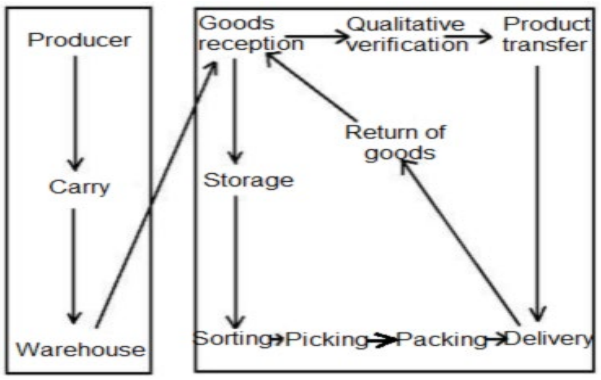

Fig. 13. Flow within the warehouse.

The first step in the warehouse is the goods receipt process. The process initiates upon the arrival of goods at the warehouse, encompassing tasks like unloading, counting, identification, quality control, and acceptance, ensuring goods meet specified quality and quantity standards. Subsequently, a receipt is issued post-unloading. Storage operations involve allocating goods to designated storage areas and identifying available warehouse locations.

An example of an application that can be used in the distribution warehouse is the Flux Vision application. This software streamlines all warehouse operations, from reception to delivery. Flux Vision also provides accuracy and control over all products in a warehouse.

Advantages of Flux Vision:

- Completely automated management of warehouse operations, regardless of complexity,
- Tailored control of stock rotation (FIFO, FEFO, LIFO, LEGO),
- Comprehensive traceability from batch-level to individual barcodes,
- Customised rules for the usage and also for the tuning of the storage space,
- Live user guidance throughout storage operations,
- 3D vision of the storage locations (Figs. 14 and 15).

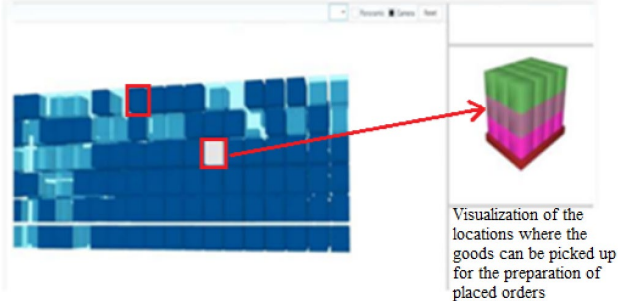

Fig. 14. Illustration of where goods can be picked up for order picking.

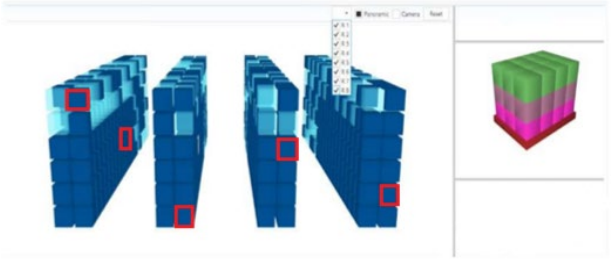

Fig. 15. Illustration of all rows and locations used for order preparation.

The information generated by this application, such as indicating supply needs, sales recorded or prospected, stock classification in several categories, expiry dates, and batches, can considerably facilitate the management of products in the distribution warehouse.

3. CASE STUDY ON THE OPTIMISATION OF A LOGISTICS FLOW IN A WAREHOUSE OF DISTRIBUTION

3.1. Logistics flow to be optimised in the warehouse

The system's optimisation includes extending the operating area and introducing AMRs in daily activities that are programmed to pick automatically according to the products ordered by each customer [7].

These AMRs determine their trajectory by tracking multiple QR codes, eliminating the risk of collisions.

Each AMR is equipped with a rotating shelf that allows all items required by the system to be picked from the picking area [7].

Simultaneously, the warehouse products are segmented into various categories, such as bulky products and small and medium-sized products, and grouped according to the supplier they come from. In this case, the AMR has a computer system that helps it identify exactly which product it has to pick, where it is located, and which address it has to reach so that the FIFO method can be used (Figs. 16 and 17).

Main features of the system:

- Optimisation and combined order selection,
- Inventory management,
- Making an accurate map of the whole area and the route the AMR has to follow,
- Heat analysis and recommendation of goods placement according to this aspect,
- Incorporation of RFID technology,
- Shelf height extends up to 2.8 meters, resulting in a 20% increase in storage capacity.

Fig. 16. Optimising the picking process using the FIFO method.

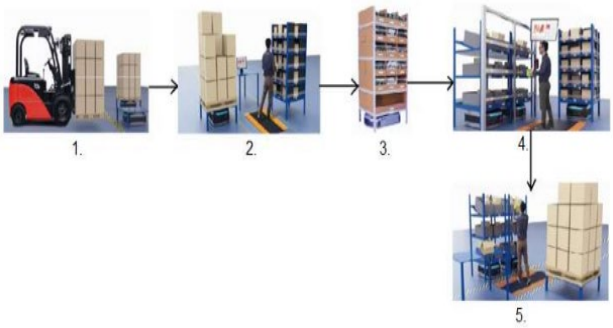

Fig. 17. The chart of the storage flow.

System benefits include:
- Prompt and efficient layout;
- Reducing the required initial investment in comparison with the traditional automation equipment,
- Reducing labour costs by 50% to 70% for handling goods,
- Reducing the workload,
- Higher effectiveness,
- Flexible addition or removal of AMRs.

Step 1: Initiating the picking process, the first step in the warehouse is to receive the goods and to address all the boxes so that the computer stock aligns with the physical stock in the warehouse.

Step 2: Once all the boxes have been received, each item is individually addressed according to its product category and, finally yet importantly, checked for quality and quantity.

Step 3: Once all items are received and addressed, they can be computer-identified by each AMR so that they can later be picked up.

Step 4: Therefore, the AMR identifies each item and transports it to the area where the order placed by the customer is picked and prepared.

Each station is equipped with an RFID scanner that has the role to scan every item, a monitor where are illustrated the addresses of the shelves picked and the name of each item, as well as a printer and several boxes necessary to store all the products.

Step 5: Place each item in a box and subsequently positioning it on a pallet located next to the picking station.

3.2. Software features of the AMR used in the picking process

The AMRs are used to ensure high box picking efficiency, reaching a rate of up to 300 boxes per hour per station; fast deployment and low ground load; and finally yet importantly, they can be connected to a variety of automation equipment, such as conveyor lines and other industrial robots [8].

3.2.1. AMR management system (Fig. 18). This system covers all operational aspects of the warehouse, including four subsystems: picking, moving, sorting and stacking.

Fig. 18. Map of the AMR management system.

The sorting system can dynamically adjust routes, improving efficiency, and is suitable for parcel, store distribution, and inter-warehouse sorting. The stacking system is intended for full pallet storage and high-level storage in the warehouse and carries out the loading and unloading of goods with full pallets in cooperation with the AGV. Each module can combine processes to form a variety of composite systems.

This AMR is a multi-agent system for task planning and management. It can be deployed in both the cloud and on-premises, with the ability to simultaneously prevent traffic congestion, allocate tasks, optimise capacities, perform emergency stops for safety, and perform other tasks associated with other time-mobile robots real, on a large scale.

3.2.2. AMR Simulation and Control Platform. Utilising the computer system, a live 1:1 simulation is conducted to aid in identifying the optimal plan and configuration prior to project initiation (Fig. 19). It validates the plan and algorithm's effectiveness and offers ongoing support for project evaluation and management. This platform seamlessly integrates planning tools, map editing tools, simulation tools, robot models, and various other modules [9].

The adaptive algorithm for controlling motion parameters, grounded in a high-efficiency control model, enables autonomous and efficient movements for various intelligent robots, ensuring high speed and stable operation (Fig. 20) [10].

Advantages:
- The motion parameters adapt accordingly,
- Decisions made for safe movement to prevent collisions,
- Trouble-free trajectory planning or flexible planning of acceleration and deceleration on the desired trajectory, meticulously monitored by multi-type controllers to ensure smooth movement.

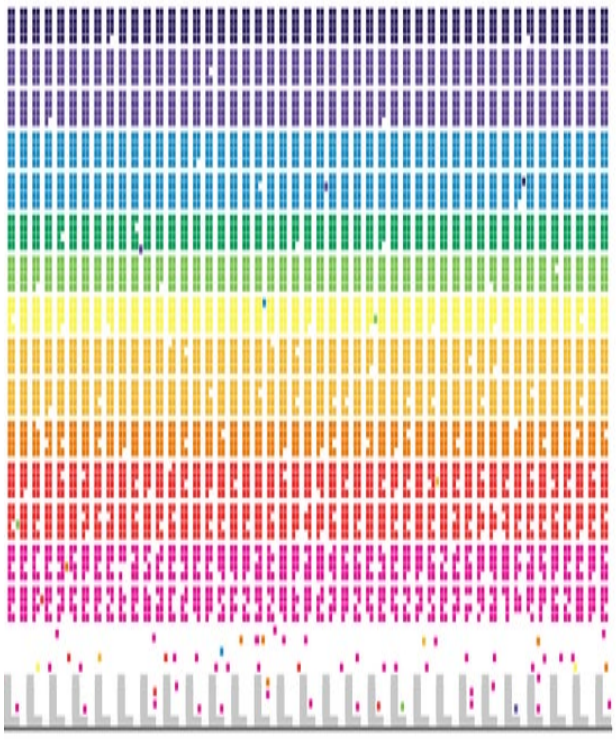

Fig. 19. Whole system simulation platform.

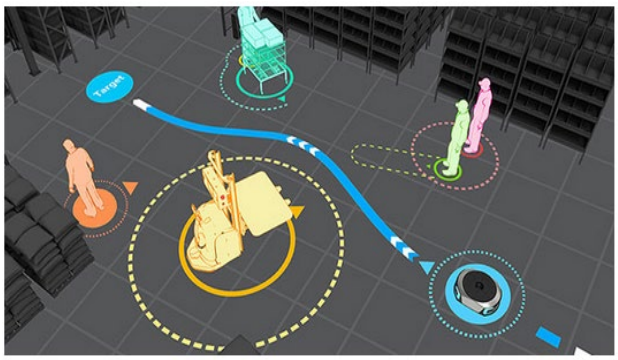

Fig. 20. AMR movement and displacement control.

3.3. Optimisation results and interpretations

The GEEK system optimises picking processes in any warehouse, reducing the number of operators, improving the quality of the process and, last but not least, helping to complete orders in the shortest possible period (Fig. 21) [10].

During the picking process, above each AMR is a shelf with multiple addresses and items needed to fill orders. Thus, the AMR is responsible for picking up the shelf and transporting it to the right of the station, where individual picking of each item is carried out. This AMR type can transfer multi-item racks, boxes, and pallets (Figs. 22–25) [48].

Improved productivity: Fewer operators are required to carry out the picking process.

- Increased accuracy: up to 99.99%,
- Lower labour costs: reduce costs by up to 50–70%,
- Meeting standards for obstacle avoidance [11].

The objectives of this optimisation involve:

- Reduce time spent on picking,
- Shorten the time it takes to pack an order,

Fig. 21. AMR GEEK+.

Fig. 22. Platform on top of the AMR.

Fig. 23. AMRs integrated into the flow.

Volume Quantites											
	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Volumes PAYS	1,011,138	5,211,224	2,512,184	3,121,954	4,123,541	4,982,485	5,442,595	6,625,667	7,927,164	8,951,423	0
Volumes Ecomm		128,582	9,792	26,262	30,002	21,005	18,201	16,005	16,008	12,991	0
	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Platforme	1,011,138	2,311,224	2,512,388	3,171,554	4,123,541	4,989,485	5,887,593	6,829,007	7,922,344	8,951,432	0
Ecommerce			9,792	26,262	30,002	21,005	18,201	16,005	16,008	12,991	0
Typologie d'articles	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
STD	835,245	1,918,316	2,005,216	2,022,222	3,422,534	4,414,702	4,886,702	5,666,702	6,576,546	7,429,683	0
HETE	23,256	53,158	57,783	72,955	94,841	114,758	157,415	157,001	182,214	205,883	0
VOLU 1	121,337	277,347	301,477	384,625	494,025	598,738	706,511	819,553	950,661	1,074,171	0
VOLU 2	27,301	62,491	67,832	85,643	111,338	134,716	158,965	154,995	212,983	241,688	0

Fig. 24. Calculation of available volumes and platforms for each station.

Subgrup	Productivitate	Total		M1		M2		M3		M4	
		QTY	CMD	QTY	CMD	QTY	CMD	QTY	CMD	QTY	CMD
		336,547	121,246	93,575	33,977	81,272	29,293	161,800	57,976	0	0
ANOM	15	6,823	945	3,023	426	2014	232	1,706	287		
BIKE	10	1,707	495	147	47	256	88	1,304	360		
MBK	20	736	736	181	181	209	209	346	346		
MHET	20	1,682	1,682	556	556	465	465	661	661		
MONO	40	39,346	39,346	12,804	12,804	10698	10.698	15,844	15,844		
MVOL	20	9,151	9,515	2,017	2,017	1699	1.699	6,799	5,799		
STAN	30	200,089	50,919	59,342	14,904	53626	13.509	87,121	22,426		
VOLU	20	76,649	17,608	15,505	2,962	12305	2.393	48,839	12,253		
		28.13	2.78	28.9	2.75	29.08	2.77	27.21	2.79		

Fig. 25. Calculation for the total number of orders as well as the number of items per product type.

- Reduce the cost of consumables used,
- Increasing the flexibility of the system,
- Optimal use of both equipment within the system and staff.

At the same time, for the system to be as optimal as possible, it is intended to realise in succession the necessary steps to carry out an order to reduce the operator's travel time significantly.

Figure 26 highlights the 3-year calculation for each piece of equipment included in the flow and the desired productivity achieved during this period. In addition, in order to optimise the activity carried out, it is essential to take into account all aspects of the workflow, including calculation of electricity consumption, efficient use of the available surface, associated personnel costs, expenses for order packaging materials, costs of maintenance, transport rates and, last but not least and any additional costs that may arise after the implementation of the system [39].

	2021	2022	2023	2024	2025
Oders	800000	1015319	1289455	1565320	1798199
Qty	2400000	3045957	3868365	4695960	5394597
Share of Packsize	15%	16%	17%	18%	20%
Orders with Packsize	120000	162451	219207	281758	359640
Qty	**360000**	**487353**	**657622**	**845273**	**1078919**
Productivity manual	25	25	25	25	25
Working hours	19200	24368	30947	37568	43157
Working hours	8128	12192	16256	16256	16256
Cost by hour	42	45	47	48	49
Manual Human Cost	806400	1096545	1454505	1803249	2114682
Human cost	**341376**	**548640**	**764032**	**780288**	**796544**
Saving on human cost	**465024**	**547905**	**690473**	**1022961**	**1318138**
Cost of Packsize machine	0	0	0	0	0
Installation cost	9760	9760	9760	9760	9760
Maintenance cost	0	0	0	0	0
Cost of convoyor + strapping machine	39040	39040	39040	39040	39040
Electricity	2016	2117	2223	2334	2450
Surface	890	890	890	890	890
Surface cost	24920	25810	26700	27590	28480
Aditional works (electricity, data cables, etc)	19520	19520	19520	19520	19520
Total Building	**95256**	**96247**	**97243**	**98244**	**99250**
Carton usage Packsize	170400	230680	311274	400096	510689
Cost of carton boxes Packsize	426000	576701	778186	1000239	1276721

Fig. 26. Calculation of each equipment in the whole stream.

In addition to these essential costs to optimise a system, if other equipment is to be included to improve the performance of the activity, the cost of the conveyors, the cost of transporting the equipment and last but not most negligible, the cost of maintenance. The optimisation of the system includes extending the operating area and introducing AMRs in the daily work that automatically pick up according to the products ordered by each customer.

4. CONCLUSIONS

The whole article highlights how to store temporary items, how to store them on the shelves, and the main functions of a warehouse. It describes all the stages a product goes through from the moment it is received in the warehouse until it is delivered. All orders in the warehouse are prepared using WMS software, and the items for that order are distributed for picking according to the FIFO method. There are situations when the picking method needs to be applied for some items, and for such cases, each operator picks the products only from specific locations. In addition, to complete an order in the shortest possible time, a method of arranging the shelves in the warehouse is chosen so that the operator can quickly retrieve all the items and, last but not least, reach the appropriate location.

The core objectives of the article focus on optimising and managing the warehouse to improve the activities carried out, including product reception time, order preparation, process automation, and, finally yet importantly, the quality of the products received and stored.

Thus, to improve the carried-out activities, an analysis is first realised on the type of warehouse, the way an order is delivered, the methods used to store products, and last but not least, the equipment used in the warehouse. All this information helps to optimise the space in the warehouse and to automate the processes carried out.

The goals defined and pursued in this work were based on optimising the current flow in the warehouse to maximize productivity and significantly increase the number of orders. Therefore, to identify all existing bottlenecks in the flow deployed in the warehouse, a simulation was performed in WITNESS Horizon, and all component element reports were extracted to analyse and interpret each percentage. After the simulation, the necessary calculations were made to optimise each process, and the entire flow was designed. In addition, bottlenecks were identified, and measures were taken to reorganise the area and optimise the flow.

The focus has been on optimising the final order's picking and packing process. Thus, the picking process is intended to be optimised by introducing AMRs that move according to specific QR codes and pick items from the shelf much faster than human operators. Under these conditions, the productivity regarding the number of picked items will increase significantly, but there are bottlenecks in packing the final order. This is also intended to optimise the final order packing process and significantly reduce the estimated time to pack an order.

Optimising a warehouse is all about making order preparation time more efficient, the time it takes to receive the products, and getting the final orders as quickly as possible. Consequently, to optimise all these processes, it is necessary to include as much automated equipment as possible to increase productivity.

All these optimisations create a logical flow within the distribution warehouse and help to make traceability much more transparent and measure activities and processes.

The solution proposed in this article could be implemented in warehouses where different types of products could be stored, including Waste of Electrical and Electronic Equipment (WEEE) collected for recycling. Thus, the collected WEEE can be temporarily stored in warehouses equipped with AMRs.

Our future research will include the development of an experimental model for a WEEE automated collection system connected to the warehouse management platform, thus, in real time, the right locations within the warehouse will be allocated for all types of WEEE collected for recycling.

The warehouse automation system using AMRs has the following benefits: increased productivity due to quick order fulfilment, timesaving and lower employee costs, as their presence, is only necessary for supervision activities.

The results of the case study highlighted in section 3.3 of this article highlight important insights into streamlining warehouse flows using AMRs. Subsequently, the implementation of a multiple AMR system is necessary for all automation processes in the warehouse.

In addition, by implementing AMRs in the warehouse, numerous advantages are added, such as a more efficient, economical and secure environment that can cope with the increasingly complex requirements of the warehouse.

In conclusion, implementing AMRs in the distribution logistics warehouse is a beneficial strategic decision, which will have a positive impact on operational efficiency, cost reduction, and overall performance improvement.

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