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Improving Retail Warehouse Activity by Using Product Delivery Data

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Featured Application: This study is dedicated to the combined examination of product delivery data and order picking strategies, as well as their application, aiming to improve retail warehouse activity.

Abstract: This paper presents a research study which is dedicated to the improvement in retail warehouse activity. This study aims to improve activity by identifying an efficient order picking strategy. (1) Background: The literature review shows the application of order picking strategies, but research related to their selection lacks an integrated approach. (2) Methods: The authors use the discrete event simulation method for the analysis of order picking strategies. The application of the discrete event simulation method enables various scenario tests in retail warehouses, allowing one to benchmark order picking strategies. By using the simulation model, experiments were designed to evaluate order picking strategies that are dependent on the delivery of the product distance variable. This research uses analysis of cost components and helps to identify the best possible order picking strategy to improve the overall warehouse performance. The authors benchmarked order picking strategies and presented constraints following product delivery data concerning their applications. (3) Results: The results presented show that the application of the order sorting strategy delivers 46.6% and the order batching strategy 6.7% lower costs compared to the single picking strategy. The results of the order batching strategy could be improved by 8.34% when the product clustering action is used. (4) Conclusions: The authors provide a theoretical framework which follows the application of order picking strategies using the product delivery data approach, which is the main scientific novelty of this paper. Recommendations are provided regarding the application of the proposed framework for the future improvement in retail warehouse activity.

Keywords: warehousing; product delivery data; order picking strategy; retail warehouse; efficiency analysis

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1. Introduction

Efficiency in retail warehouses is linked with product delivery terms and conditions, on-time delivery aspects, volume traffic, and the selection of gates for unloading the products [1–9]. Many of these process management aspects are still not properly conducted and require an integrated approach.

Due to the lack of an integrated approach, the increase in economic efficiency focuses on transport or warehouse optimization, and these separate optimizations are not unified.

Warehouses with manual technologies have demonstrated possibilities to reduce operating costs, increase the organization of work, and improve environmental and resource management. However, the efficiency of labor-intensive warehouse processes depends on the delivery process, delivery distance, and the timeliness of product arrival [10–18]. Product delivery is also differentiated by using the transport mode, time, and location constraints.

As the volume of the delivery traffic grows, the performance of retail warehouses becomes more important and is considered vital to the success and competitiveness of business companies. Therefore, this research study aims to identify variables having an impact on the warehouse performance activity by analyzing product delivery data and order picking strategies. Later, order picking strategies are compared to minimize warehouse activity costs associated with the handling of incoming products.

The proposed research study includes several parts. The multi-layer methodology, which focuses on the application of order picking strategies, is presented in the next chapter. Further on, a literature review on various order picking strategies and product delivery data is provided. Based on investigations, the authors deliver an empirical study and present the results of the application of different order picking strategies in which selection follows product delivery data. Finally, the discussion of results is summarized in the conclusions.

2. Methodology for the Selection of the Order Picking Strategy

Warehouse activity depends on many other constraints that are important for making strategic decisions. For the revision of retail warehouse activity and the selection of the order picking strategy, the authors created a methodology, which follows an integrated approach.

The framework of the methodology is presented in Table 1 and involves three layers helping to compare and select a proper order picking strategy. Various methods proceed with theoretical and empirical data analysis. This allows us to benchmark order picking strategies by using product delivery data and select one which provides the best results on warehouse activity performance improvement.

Table 1. The description of the proposed multi-layer methodology.

No. of Layer	Functional Aspect	Methods	Results
The first layer (criteria for the selection of order picking strategy)	Review of the criteria presented in the literature	Classification of criteria having an impact on order picking strategy	The extension of current knowledge in linking transport and retail warehouse activities
The second layer (product delivery distance data in selecting order picking strategy)	The selection of order picking strategies by using product delivery distance variable	The design of the theoretical framework for empirical investigation	Evaluation of distance variable and the selection of the best results providing order picking strategy
The third layer (application of order picking strategy)	The revision of the application of order picking strategies and product delivery possibilities	Comparative analysis of order picking strategies supported by product delivery data	Benchmarking of order picking strategies using product delivery data and its results provision

This research covers the knowledge gaps that exist due to the lack of an integrated approach. It provides the methodology and the revision of order picking strategies important for the improvement in retail warehouse activity.

All the layers of the proposed methodology are interlinked, aiming to provide a theoretical and practical response to the problem setup.

2.1. The Revision of Order Picking Strategies by Using Product Delivery Data

There are different order picking strategies stated in the literature. In manual warehouses, several "men-to-goods" order picking strategies are used. Regular warehouses involve order picking of various products according to single or multiple orders. Products (cases) are placed on the pallets that are shipped to final customers. The most well-known order picking strategies are summarized below under the problem families (see Table 2).

Table 2. Order picking strategies.

Picking strategies	Problem Family	References
Picking single order (or pick-by-order)	Discrete picking	[5]
Parallel picking of multiple orders (or sort-while-pick)	Parallel picking	[6]
Picking batch and sorting into multiple orders (or pick-and-sort)	Batch picking	[3,7]
Sorting after picking into multiple orders (or picked-to-sort)	Subsequential sorting	[8]
Full-pallet picking (or unit load picking)	Cross-dock	[9]

Picking single order strategy (single picking strategy). The assembling of products according to an individual order is called picking a single order. This strategy follows the process of picking items from the storage area for a specific customer's order. This order picking strategy allows the retrieval of products for a single order. Following this order picking strategy, products are picked and collected from storage locations, which are visited by the order picker. This is the most often applied order picking strategy since it is simple. The orders are not scheduled and could be executed at any time during the working shift. The proposed order picking strategy requires a significant amount of routing (traveling) of the order picker compared to other order picking strategies. This order picking strategy is the most labor-intensive activity, where 60% of the labor corresponds to traveling between product locations [10].

Parallel picking of multiple orders strategy (parallel picking strategy). Picking of products according to several orders is called picking of multiple orders. Following this order picking strategy, the same product is picked in parallel based on the orders for products that are allocated for the same order picking route.

Picking batch and sorting into multiple orders strategy (order batching strategy). Batching is a process to group a set of orders into so-called batches to reduce the total order picking time. With order batching, multiple orders are combined, which are later sorted into a specific customer's order in a sorting area. All the pallets with picked products are moved for the temporal storage (forward area), where they are allocated for the sorting process. Batch picking is performed in the forward storage area by utilizing forklift operators from storage locations or by order pickers from the picking locations. These operations are handled before the start of the consolidation and shipping process [11]. This order picking strategy is highly investigated in the literature since it enables reducing the number of routes required to retrieve products. It enables picking multiple products from multiple orders at the same time, which need to be sorted later.

Sorting after picking into multiple orders strategy (sorting strategy). In a JIT-operated warehouse, a warehouse worker sorts the pallet of a particular product and travels through the warehouse to distribute products of that pallet to a specific customer. This difference in the sorting operation affects the layout of the warehouse [9], as it requires a sorting area for such operational processing.

Full-pallet picking strategy. In retail warehouses, some pallets are retrieved as closed unit loads (full pallets). These pallets do not involve picking individual cases, since they are moved by forklifts to the storage area or directly to the outbound area. Such a picking strategy is quite common for hypermarket stores.

Talking about product delivery distance aspects, the most often named are long-distance and short-distance deliveries.

Long-distance delivery. This type of delivery involves the delivery from single product-constructed (homogeneous) pallets from the original warehouse to the destination place. The height of the pallets is around 2 m, helping to reach the highest vehicle occupancy. After the inbound process, the pallets are stored in a wide-aisle (WA) warehouse [1].

Short-distance delivery. This delivery type involves the delivery of various size pallets and/or small-sized packages (cartons) from the original warehouse to the destination warehouse. Short-distance delivery implies the involvement of much more customers in the delivery route than the previously described delivery type. After the inbound process, the pallets are stored in a wide-aisle and/or narrow-aisle warehouse [2].

JIT product delivery (JIT delivery). JIT delivery differs from the existing studies and extends the focus from production to the production–retail environment. This strategy involves the delivery of pallets combining different heterogeneous products from producers' warehouses to a retail warehouse. The height of the pallets is much lower than the maximum height and is dependent on the accumulated volume demanded by customers. Due to that, the occupancy of the vehicle is significantly lower. After the inbound process, the pallets are temporally stored at the inbound area for picking and delivery to retail stores [3].

Hybrid delivery. This type of delivery involves the delivery of heterogeneous pallets from the original warehouse to the destination warehouse and pick-ups of the returns of cartons back to the original warehouse [4].

The above-mentioned order picking strategies are different in their processes. Additionally, the results of their application depend on product delivery data. Further on, the order picking strategies are revised in a more detailed way.

2.2. The Application of Order Picking Strategies in Retail Warehouses

The application of order picking strategies receives a lot of attention from researchers. The authors performed a literature review to gather order picking strategies and the aspects of their application [12–20].

Most of the manual order picking strategies involve the "men-to-goods" order picking process. This picking process can be described as follows: The order picker starts the order picking route from the depot location. Next, the order picker travels (or drives the appropriate forklift truck) through the warehouse and collects items from different storage locations. Next, the order picker returns to the depot location and places the collected products. For the picking process, the order picker uses an order list, which contains products that appear in a single customer's order or many customers' orders. The formation of picking lists for the picking of multiple orders is a complex process. Many heuristics are applied for the formation of picking lists. Four of them will be described below.

The first group of heuristics follows the priority rules, where customer orders are ranked according to a priority score and then assigned to the routes that follow this rank [21]. The second group of algorithms follows the rule of first-in-first-served (FCFS). The third group of heuristics includes saving algorithms, such as Clarke and Wright's algorithm used to minimize the traveling [22] distance. For each pair of customer orders, distance savings can be made by collecting all the products of several customers' orders in one (large) route instead of collecting products in several separate routes [23]. Finally, the last group involves seed algorithms implemented by Elsayed [24], which continuously generate order picking lists. The customer order is selected for picking as the initial order. Additional customer orders are assigned to that picking list according to the order match rule proposed by Ho et al. [25].

When it comes to the order batching strategy, two steps are included: the order consolidation step and the order sorting step. Two approaches to order consolidation could be distinguished: (1) static—all orders are known in advance; (2) dynamic—the orders of customers become available over time. For order consolidation, the customers from the specific region could be grouped by applying the static or dynamic method. The dynamic possibility exists if the vehicle delivery route is still under construction.

However, for the order batching strategy, all customers' orders must be known in advance. Products are picked at the primary storage area and delivered for sorting to the JIT area. In the sorting area, all customers have predefined places which are fixed.

The studies are grouped according to the research field and the application of order picking strategies in various warehouses (see Table 3). Many reviewed publications focus on traditional warehouses [12] and the application of the single picking strategy.

Table 3. The application of three order picking strategies.

Order picking Strategies	Subject	Author
Single picking strategy	Retail warehouse	[26]
	Traditional warehouse	[27,28]
Order batching strategy	Retail warehouse	[29–32]
	Traditional warehouse	[33–37]
Order sorting strategy	Traditional warehouse	[38]

Based on the literature review, we found out that there are many research studies highlighting the order batching strategy, and some other studies highlight a single order picking strategy.

Regarding the research papers from the field of traditional warehouses, there are approximately seven important research papers, although based on our extensive literature review, we found out that there is a lack of research studies dedicated to the investigation on combined (integrated) strategy application in a retail warehouse.

Research gaps: The extensive literature review shows that researchers focus on: (i) various investigations in different problems, (ii) the criteria important for strategic decisions, and (iii) the application of order picking strategies. However, these strategies are usually not linked with product delivery data to reach higher efficiency (throughput performance). Therefore, in this paper, the authors link order picking strategies with product delivery data and revise their application results in a retail warehouse.

3. Review of the Criteria Important for the Selection of Order Picking Strategy by Using Product Delivery Data

A review of beneficial criteria important for the selection of the order picking strategy by using product delivery data is presented in Table 4. These criteria represent the important aspects for the selection among alternatives in managing product delivery and the order picking process. Prioritizing different criteria is a complex procedure and is outside the scope of this research work.

Table 4. Review of beneficial criteria important for the selection of order picking strategy by using product delivery data.

No	Name of Criteria	Positive Results after the Implementation of Order Picking Strategy by Using Product Delivery Data	Authors
1	Large variety of products	Order sorting strategy, JIT delivery	[39]
2	Short product lifetime		[40]
3	Product quality	Order sorting strategy, JIT delivery	[41]
4	Higher service quality	Order sorting strategy, JIT delivery	[42–44]
5	Synchronization of delivery and picking schedule	Order sorting strategy, JIT delivery	[40,45]
6	Sharing information	Order sorting strategy, JIT delivery	[46]
7	Reduction in inventory level	Order sorting strategy, JIT delivery	[47]
8	Reduction in costs	Order picking from storage strategies: single picking, parallel picking, order batching strategies	[48]
9	Increase in pickers' productivity	Order sorting strategy, JIT delivery	[9]

According to the review of criteria which are important for the selection of the order picking strategy by using product delivery data presented in Table 4, a positive relation for product quality [41], delivery service quality [43,44], delivery schedule synchronization [40,45], and inventory reduction [47] is indicated after implementation of the combined JIT delivery and order sorting strategy.

Product Delivery Data: Distance Variable

The selection of the order picking strategy is dependent on product delivery data. For reaching efficiency in retail warehouses, the delivery distance parameter could be utilized.

Regarding the product delivery distance, Chen et al. [42] suggested JIT deliveries for cases when the distance between warehouses is 50 km or less and stated that longer distances are not suitable for JIT delivery. However, researchers [49,50] analyzed a JIT warehouse located 140 km away from producers and confirmed that such distance provides a possible solution.

From the above examples, we can notice that the variable describing the product delivery distance is significant in selecting an order picking strategy.

According to Eurostat [51], freight delivery by road distance is classified as international (long-distance delivery) and national (short-distance delivery). The average distance length is almost 600 km (i.e., 581 km) in the European Union territory for the long-distance delivery case. Most products are transported from 300 to 999 km, but there are cases when delivery distances are longer or shorter. The actual long-distance delivery length depends on the size of the country and its participation in international transport activity. However, the focus on deliveries longer than a 1000 km distance by trucks has significantly reduced in recent years [51].

The average distance length for the short-distance delivery case is less than 149 km. Short-distance product delivery is performed inside the domestic market and in some so-called islands. There is also an increase in demand for such deliveries.

As we can see, the range between 150 and 299 km is not covered in the literature; therefore, we suggest calling it intermediate-distance delivery. Nevertheless, there is a significant reduction in deliveries in this distance group [51].

Based on the literature and statistical investigations, we assume in Table 5 such distance classification.

Table 5. Product delivery data: distance criteria.

No	Distance Criteria, km	Product Delivery
1	Up to 140 km	JIT delivery
2	Up to 149 km	Short-distance delivery
3	Between 150 and 299 km	Intermediate-distance delivery
4	Between 300 and 1000 km	Long-distance delivery

Products that arrive in the warehouse in the long-distance mode could be processed by applying order picking from storage strategies such as single picking and order batching strategies (Figure 1A,B).

Products that arrive at the warehouse in the short-distance mode could be processed by applying a proposed range of strategies (A, B, C) and could follow the order sorting strategy (C) which is simpler compared to other order picking strategies. The sorting strategy is an order picking method that facilitates the fast movement of consolidated products between producers and retailers in the supply chain. It also allows eliminating storage and traveling between product locations, which are expensive operations of any typical warehouse. After inbound and outbound vehicles are located to designated doors, goods from incoming vehicles are unloaded, sorted at the sorting area, and loaded into outbound vehicles with the minimum storage duration between them. The delivery of such products matches the processing of the JIT delivery option.

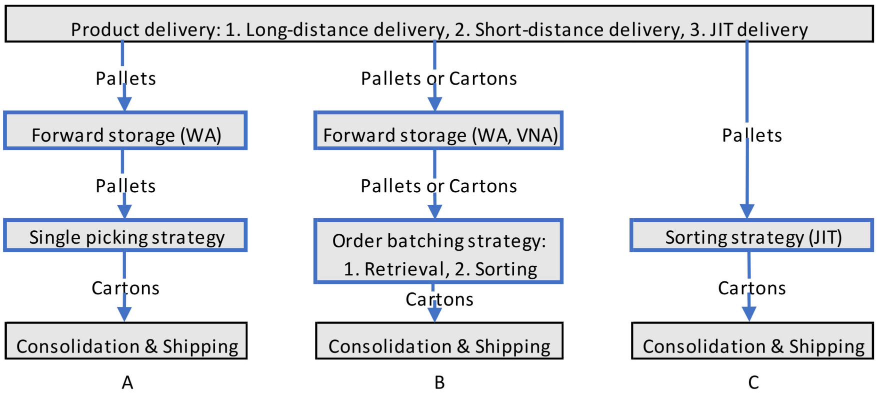

Figure 1. Mixed schemas of order picking strategies by using product delivery data. (**A**)—product delivery combined with single picking strategy; (**B**)—product delivery combined with order batching strategy; (**C**)—product delivery combined with sorting strategy.

4. Development of Empirical Research Model

4.1. Theoretical Framework

To revise the order picking strategies, the authors applied the discrete event simulation method to the research study. During the simulation, only the orders of business customers (B2B) are taken. Such orders have more products (up to 70 products) than individual orders, which are small and contain, on average, four–five products.

Herein, we also analyzed the size of B2B customers' orders and the probability that customers select the same products. In our research study, we performed statistical analysis, aiming to identify the correlation between orders' size and the travel distance. Later, we identify common products among the presented customers' orders.

In our model, there are two matrices: one is a matrix of product locations (designated as a), and the other is a matrix of products (i.e., order lines designated as z). For example, a product's location (a_1) occurs in the orders of customers (v)as order lines (z) with the defined quantity required for each customer (1).

$$\begin{bmatrix} a_1 \\ a_2 \\ \vdots \\ a_n \end{bmatrix} \Leftrightarrow \begin{bmatrix} z^1_{a1} & z^2_{a1} & \cdots & z^v_{a1} \\ z^1_{a2} & z^2_{a2} & \cdots & z^v_{a2} \\ \vdots & \vdots & \vdots & \vdots \\ z^1_{an} & z^2_{an} & \cdots & z^v_{an} \end{bmatrix} \quad (1)$$

For retrieval of products from common products, locations are identified, and the number of customers that have ordered the specific product is identified. If some products are ordered by at least several customers, the quantities which appear in their orders are summed to obtain the total amount (Q).

The mathematical Equation (2) helping us to define the rate of common products is presented below:

$$P = \left(\frac{z^{v>1}_{anQ}}{a_{nQ}}, Q >= 0\right) \quad (2)$$

where P is the common product rate, presented as a percentage; Q is the consolidated quantity ordered by business customers.

The explanation of Equation (1) is provided below in Figure 2. Order lines placed by the v customer $(z_1, \ldots, z_v)$ may differ from the order lines required by other customers and by the quantity ordered. Therefore, we identified (a_{nQ}) product locations being ordered by customers and placed quantity $Q > 0$.

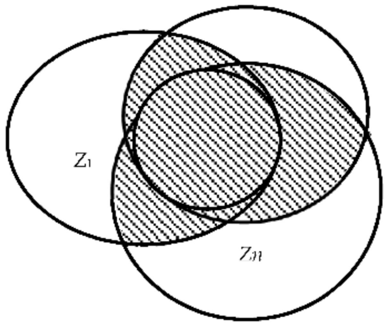

Figure 2. A common selection of product positions.

A simulation study was performed for the retail warehouse presented in Figure 3.

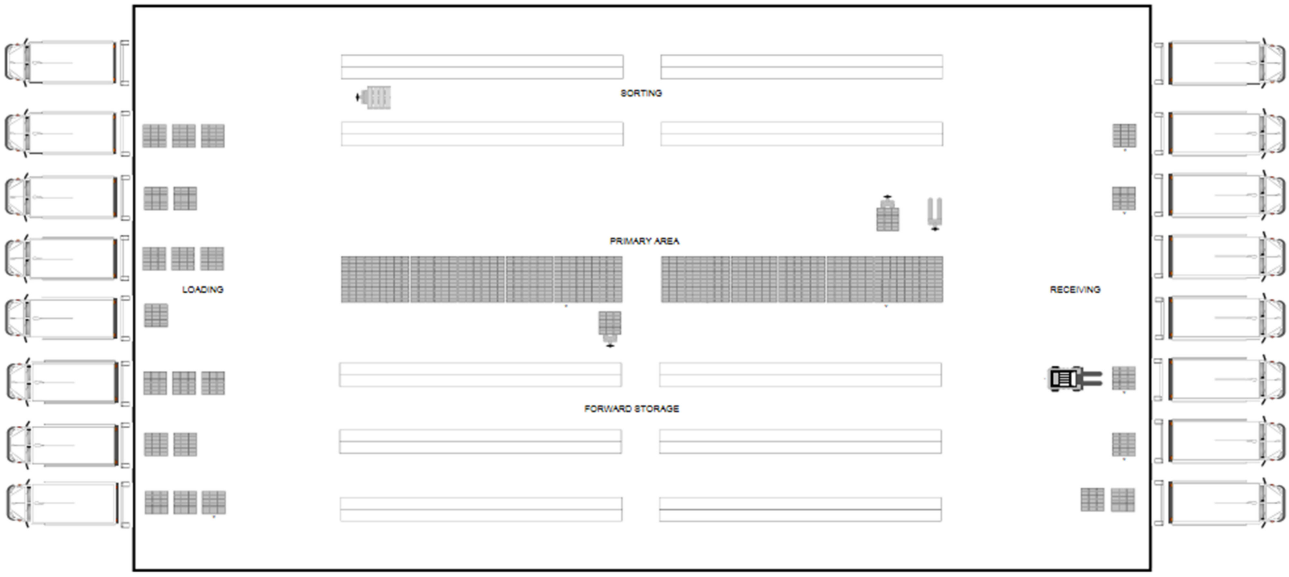

Figure 3. Research wide-aisle warehouse.

The performance of the single order picking strategy is performed in the forward storage area, while the order batching process is delivered in all presented areas, except the receiving area. The orders of business customers are collected and placed on pallets (i.e., on average, two pallets are allocated per customer), and in total, 2394 business customers' orders are retrieved.

The empirical study of our research (presented in Section 5) consists of three main parts: statistical analysis, simulation results, and the comparison of order picking strategies.

Based on the literature review, the authors indicate order picking strategies which are important for retail warehouses serving B2B customers. In this research study, the authors implement the discrete event simulation method. Based on the simulation results, three order picking strategies are compared.

The proposed research enables cost analysis and helps to select the best order picking strategy, aiming to increase efficiency, which is important for warehouse managers, and its application matches product delivery options.

4.2. Cost Analysis

The best way to compare order picking strategies to compare their effectiveness is by identifying and analyzing costs. For such analysis, the authors used the labor and the equipment costs.

Herein, d_t—traveling in the forward storage area; d_x—traveling from the forward storage area to the primary area; d_p—traveling from the primary area to the sorting area; d_s—traveling in the sorting area; d_o—traveling to the loading area.

The maximum number of orders (w) needs to be defined before the picking of orders starts. The maximum number (w) is equal to the number of orders per period.

All orders have their picking sequence, which is different to the orders' delivery sequence. The picking starts from the order (w_{max}) and ends with the order (w_1).

In the warehouse, there are several areas: receiving area, forward storage area, primary area, and sorting and loading areas.

During the order picking activity, the employee moves between those areas to deliver the process. The travel distance of the employee is calculated according to the equation presented below (3):

$$D_{Bj} = \sum_{t=1}^{n} d_{tj} + \sum_{x=1}^{y} d_{xj} + \sum_{p=1}^{z} d_{pj} + \sum_{s=1}^{v} d_{sj} + \sum_{o=1}^{w} d_{oj} \quad (3)$$

where D_{Bj} is the total distance for the employee route j; n is the number of products; y is the number of cartons; z is the number of order lines; v is the number of customers; w is the total number of B2B orders.

Order picking traveling distance components are presented in Figure 4.

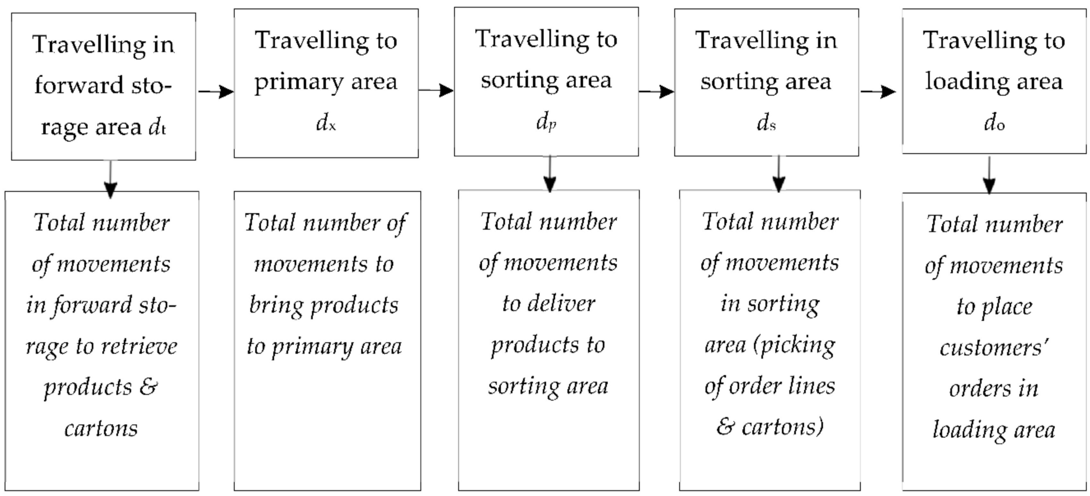

Figure 4. Order picking traveling distance components.

Each movement of the order picker could be converted to costs by multiplying distances from the labor and the equipment cost components (4):

$$C^{st}_{Bj_1} = D_{Bj} \cdot (c_L + c_E) \quad (4)$$

where c_L is labor costs per movement (meter); c_E is the equipment costs per movement (meter).

Equation (5) is used to identify the best order picking strategy, which was proposed by [52]:

$$\mathrm{Min}\left\{C^{st}_{Bj_1}, C^{st}_{Bj_2}, C^{st}_{Bj_3}\right\} \quad (5)$$

where $C^{st}_{Bj_1}$ is the costs per single picking strategy; $C^{st}_{Bj_1}$ is the costs per order batching strategy; $C^{st}_{Bj_3}$ is the costs per sorting strategy.

The model output is calculated by using Equation (3), which provides the possibility to compare different order picking strategies.

To revise the distances of products' delivery from suppliers to the retail warehouse, the authors applied the Euclidean distance calculation method, helping to identify the length of deliveries.

5. Results of Empirical Research

5.1. Statistical Analysis

The current warehouse has applied the single picking strategy for a long time. When comparing order picking strategies, it is necessary to examine the effect of the order size on the order picking traveling distances. This effect is investigated for the single picking strategy by using statistical analysis.

During our research study, we established that a stochastic relationship exists between the order picking traveling distance and order size, although it is evident only for the single picking strategy. The results of this research study are presented in Table 6.

Table 6. Correlation results: single picking strategy.

Regression Data	Equal to	Values
Correlation coefficient	=	0.82
R-squared	=	0.686125
T statistic	=	76.326
T table	=	1.96
Coefficients	=	
a0	=	58.921
a1	=	1.89168
The adequacy of the equation	=	
F statistic	=	5825.65
F table	=	3.84

In the examination of the single picking strategy, the relationship is quite strong. The correlation coefficient is significant, and the regression equation is adequate for the real situation.

Below, the order picking traveling distance in various aspects for each strategy is presented. Herein, the authors received such results (see Table 7).

Table 7. Correlation of scenarios.

Lines	From Storage Area (i.e., Forward Storage) Single Picking Strategy	From Storage Area Order Batching Strategy		From Receiving Area Order Sorting Strategy
		From Forward Storage Area Retrieval from Storage	From Primary Area Sorting by Customers' Orders	
Travel distance per order (meters)	88.79	60.43	95.18	95.18
Dispersion	51.49	25.06	19.54	19.54

In Table 7, the area from which products are retrieved to fulfil order picking is stated. In Figure 3, the location of each area is presented. The distance between the sorting area and the receiving area is the same as the distance between the sorting area and the primary area.

As Figure 5 shows, the travel distance for the order batching strategy does not increase per order (regardless of the number of products per order).

To fulfil picking according to the single picking strategy, the order picker returns to the same product location many times. However, during the order batching strategy, the volume per product is summed, and the order picker picks the product (i.e., batch) once per shift. Later, the order picker sorts the batch for each customer.

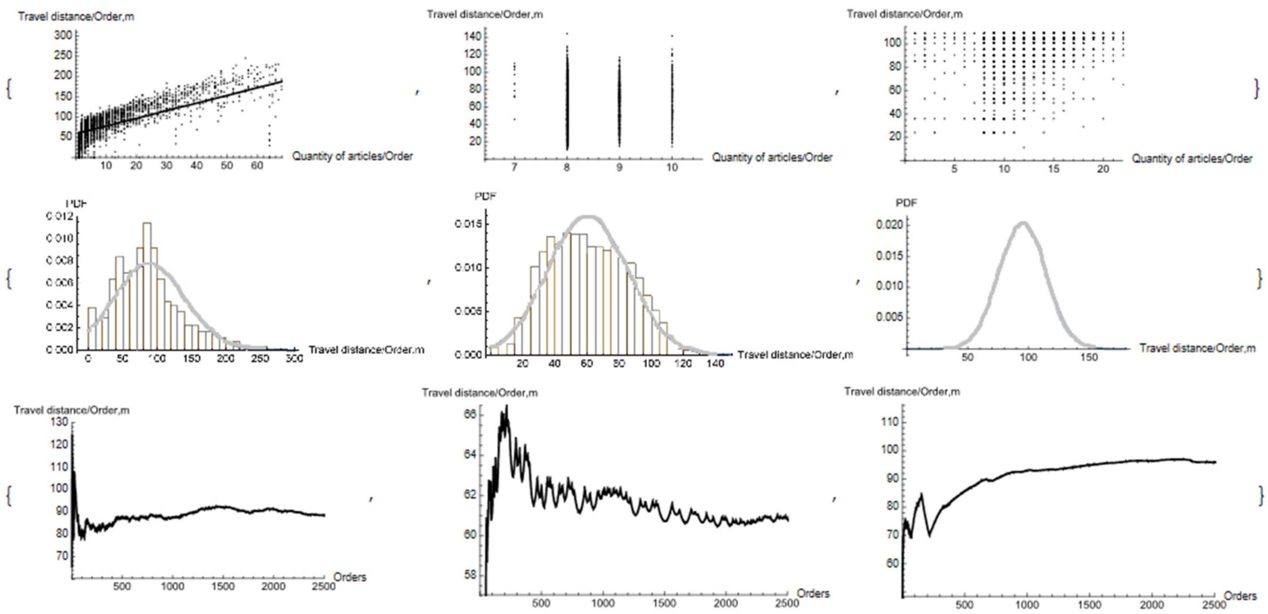

Figure 5. Travel distance per order and probability density (scenarios conducted by the authors by utilizing the statistical data): single picking strategy (on the left), order batching strategy (*a*—retrieval from storage, *b*—sorting by customers' orders) (*a*—in the middle, and *b*—on the right), and sorting strategy (on the right).

The authors also defined the delivery of the product distance variable and present the actual delivery distance to the investigated retail warehouse (see Table 8).

Table 8. Product delivery data: the actual distance.

No	Distance Criteria, km	%	Product Delivery
1	Up to 140 km	47.4%	JIT delivery
2	Up to 149 km	47.4%	Short-distance delivery
3	Between 150 and 299 km	11.7%	Intermediate-distance delivery
4	Between 300 and 1000 km	40.8%	Long-distance delivery

Products under short-distance delivery could be transferred to the JIT delivery type. Such a proposal is valid for almost one half of all products which arrive at the retail warehouse.

5.2. Simulation Results

To perform the experiments, the B2B orders were entered into the simulation model. The 2394 customers' orders include 40,724 order lines. There are small customer orders (1172 orders) that contain up to 10 order lines, medium customer orders (1078 orders) that contain from 10 to 50 order lines, and large customer orders (i.e., 417 orders) that contain more than 50 order lines. These input data represent orders that are placed to the retail warehouse for a one-month period. After the experiments, the results are summarized. The total traveling distance was calculated for picking all orders.

The results of the simulation study show the following for the next relationship:

- The single order picking strategy total travel distance (D_{Bj1}) equals 236,846 m (for traveling in the forward storage area and traveling from the forward storage to the loading area);
- The order batching strategy total travel distance (D_{Bj2}) equals 324,148 m: 111,556 m travel distance is required for product retrieval from the storage (traveling in the forward storage area and delivery to the primary area) and 212,592 m for sorting according to orders (for traveling from primary area to sorting area, traveling in the sorting area, and traveling from sorting area to loading area);

- The sorting strategy total travel distance (D_{Bj3}) equals 212,592 m for sorting to business customers' orders (for traveling from receiving area to sorting area, traveling in the sorting area, and traveling from sorting area to the loading area). The receiving area is located at the same distance as the primary area, and the sorting area has the same attributes.

The average traveling distance per order is normally distributed and presented in Figure 5.

For the application of cost components, the authors calculated the labor costs. To collect all orders of business customers in the proposed case study, four employees are required. On average, under the single picking strategy, it is possible to pick 60 order lines per working hour. However, the retrieval of products from storage allows retrieving 30 products or 300 order lines per working hour (i.e., one retrieval, on average, contains an accumulated order of 10 customers). Additionally, the sorting to orders process is less time-consuming, and the order picker handles, on average, 120 order lines per working hour.

According to [53], which proposed calculating the daily costs of the order picker, the authors calculated the costs. (a) Following the data of the Republic of Lithuania, one order picker costs approximately EUR 40 per day (8 h) or, i.e., EUR 5 per hour gross value [54]. These considerations were used to calculate the labor costs per order line (c_L). (*b*) The authors checked the costs for order picking equipment (powered pallet truck called E-Truck HD EPT20-25WA) from Howard Handling [55]. The average costs per life cycle are EUR 7214 or EUR 5 per day if the depreciation period is 5 years. If 8% of equipment costs are dedicated to maintenance and repair, then the total equipment costs are approximately EUR 5.4 per day. These assumptions were applied to obtain the equipment costs per order line (c_E).

Note: the labor costs per order line are different from country to country in the European Union countries and are based on the level of the national economy.

For the application of the second and third strategies, the same equipment resources were used in the reference warehouse.

Finally, the cost components are presented in Table 9, where the traveling distance is measured in meters. The average number of meters per order line is 5.7 m.

Table 9. Components of costs (based on the Lithuanian economy).

Components of Costs	Single Picking Strategy	Order Batching Strategy		Order Sorting Strategy
EUR/Order Line		**Retrieval from Storage**	**Sorting by Customers' Orders**	
Labor costs c_L per order line, EUR	0.015	0.003	0.007	0.007
Equipment costs c_E per order line, EUR	0.017	0.003	0.008	0.008
Total costs per order line, EUR	0.033	0.022		0.015
Difference comparing with single picking strategy per order line, %	–	33.37%		53.37%
The average difference comparing with single picking strategy per order line, %	–	43.37%		

Following the results presented in Table 9, we see that the order batching and order sorting strategies outperform the single picking strategy when costs are specified per order line.

5.3. Comparison of Order Picking Strategies by Using Product Delivery Data

The results show that the order batching strategy, according to Equation (5), outperforms the single picking strategy by 6.7%, and at least 35% of products (p = 35%) are common in B2B orders. Both these strategies are applicable for picking orders for which products overcome long-, intermediate-, and short-distance deliveries.

For higher efficiency, the authors revised, on a daily basis, the number of common product positions and the number of order lines and found that there are days with 28% of equal products (p minimum value) and other days with more than 42% of equal products (p maximum value) (see Table 10).

Table 10. Common products index.

Summary of Statistics	Minimum	Maximum	Mean	Standard Deviation
Index size, %	28	42	35	11.8

The review of orders shows that consumers make a different trade-off when selecting products. B2B customers place orders with less than 50 order lines. The size of their orders depends on the number of available products.

The authors suggest clustering B2B customers into at least three groups according to their order lines, seeking to save costs for the retrieval activity. This is especially important for B2B customers, who are looking for a limited number of product positions. After clustering products, the authors repeated the simulation study and reached better results. The installation of such a product's clustering and placement action increases savings for picking according to the order batching strategy from 6.7% to 8.34%.

The order sorting strategy shows the best results compared to the single picking strategy and the order batching strategy. Comparing the order sorting strategy with the single picking strategy, the costs (according to Table 9) are 53.3% lower, and comparing the same strategy with the order batching strategy, the costs are 33.3% lower. On average, the difference is 43.3%. However, the order sorting strategy could be applied only for products following the JIT delivery concept during shipment to the retail warehouse. According to Table 8, this strategy could be implemented in the warehouse for almost one half of products and must be combined with other order picking strategies.

6. Discussion

The authors analyzed the application of order picking strategies in a retail warehouse. The selection of order picking strategy depends on product delivery data that are predefined in advance. The authors provided investigations that are important in decision making for the selection of the order picking strategy which is dependent on product delivery options. Therefore, the decision concerning which order picking strategy is the most efficient to apply needs to be made by revising costs.

According to the literature review, most of the authors focus on the application of the single order picking strategy in retail warehouses and the application of the single picking, order batching, and order sorting strategies in traditional warehouses. In this research paper, the authors investigated three order picking strategies in a retail warehouse. These analyses were performed by taking into consideration the B2B case study.

The authors provided a case study, according to which the most efficient strategy is the order sorting strategy, which could be applied for products following the JIT delivery concept. Benchmarking is provided by applying analysis of costs, which helps to identify improvements in warehouse activity. Nevertheless, the analysis of the delivery distance variable shows that this order picking strategy could be applied partly as half of the products arrive by overcoming longer distances.

Nevertheless, such an application has some limitations, which must be included in future considerations. The authors presented the criteria which are important for decision making. One of these is the criterion describing the product delivery distance. The authors also provided mixed schemas for the application of order picking strategies as part of the decision-making process following product delivery data.

The future research directions could cover the cost analysis for the application of "goods-to-men" order picking strategies. Additionally, the authors presented the evaluation of other benefits, such as the impact on storage costs, product shelf life, and delivery service, for analyzing the improvement in warehouse activity, as suggested by other authors, under criteria evaluation. For further considerations, the authors suggest using the provided methodology, whose application supports the selection of order picking strategies by revising product delivery data. The main aspect of the methodology is dedicated to the involvement of a variable representing product delivery data.

7. Conclusions

This paper dealt with investigations to increase efficiency in a retail warehouse. The processes in a retail warehouse are quite complex; therefore, to reach the goal, many strategies need to be revised. The review of the literature showed that different order picking strategies have been studied in different problem families. However, the application of these strategies must match product delivery data, which must be researched in an integrated way.

In this paper, the authors integrated product delivery data to explore the potential for efficiency gains by selecting a proper order picking strategy. The authors developed and proposed a theoretical framework and presented its practical application. Using this framework, it is possible to determine which order picking strategy makes operations more efficient in retail warehouses. During the discrete event simulation analysis, the authors identified the best performing order picking strategy and estimated the cost savings by using a cost analysis approach.

The presented results show that the application of the order batching strategy delivers around 6.7% lower costs. The analysis of order lines showed that there are specific products which are repeatedly ordered by several B2B customers. Due to this, the authors proposed the product clustering option, seeking to place these products closer for faster retrieval. Such a solution increased the savings up to 8.34%, which is higher comparing with products with a non-clustering solution.

The results of the application of the order sorting strategy outperform both the single picking and order batching strategies by presenting lower costs results, which are, on average, 43.3% lower. However, this strategy could be applied only in the case the products are shipped to the retail warehouse according to the JIT delivery concept. The results show that only one half of the products could be delivered this way. Due to that, the efficiency increase in the warehouse could be reached in combination with other order picking strategies.

The results delivered in this paper help to improve the activity in retail warehouses, by applying the order picking strategy, which requires less labor and equipment resources during the execution and thus presents lower costs.

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