Improving The Order Pickup Process in Warehouses by Instant Couriers Through Zone-Based Assignment

Danti Ardianti Soesanto[1], Valeriana Lukitosari[2]
[1,2]Master of Technology Management Study Program, Interdisciplinary School of Management and Technology, Institut Teknologi Sepuluh Nopember, Indonesia

Article Info

Article history:

Received 2026-01-14
Revised 2026-01-26
Accepted 2026-02-26

Keywords:

Instant Delivery
K-Means Clustering
Order Pickup Process
Zone Picking

ABSTRACT

The expansion of e-commerce has intensified operational pressures on warehouse logistics, particularly for instant-delivery services, where speed and accuracy are critical. At Warehouse A of Marketplace ABC, the order pickup process experienced inefficiencies due to alphabetical sorting and courier assignments that were not aligned with the physical order placement, resulting in longer pickup times and frequent errors. This study aims to optimize the instant courier pickup process by redesigning order sorting and courier assignment through zone picking based on delivery location similarity. An applied quantitative case study was conducted using 61,577 historical instant delivery orders from July 2025. Delivery locations were clustered using K-means, and the optimal number of zones was determined using the Elbow method. The analysis yielded five optimal picking zones, which were subsequently implemented in the warehouse pickup workflow. The redesigned process significantly improved operational performance, reducing the average pickup time from 6.7 minutes to 1.7 minutes and achieving 100% pickup accuracy. These findings confirm that integrating zone picking with clustering-based zoning effectively enhances efficiency and accuracy in instant courier warehouse operations.

This is an open-access article under the CC BYSA license.

Corresponding Author:

Danti Ardianti Soesanto
Master of Technology Management Study Program, Interdisciplinary School of Management and Technology, Institut Teknologi Sepuluh Nopember
Email: danti2okt@gmail.com

1. INTRODUCTION

The COVID-19 pandemic has fundamentally altered consumer purchasing behavior, accelerating the expansion of e-commerce and intensifying competition among online marketplaces [1]. As transaction volumes continue to grow, logistics systems are required to support faster, more accurate, and more reliable delivery services [2]. In response to these demands, instant delivery has emerged as a key competitive feature for large e-commerce platforms in Indonesia, including Blibli, Tokopedia, and Lazada [3]. However,

 https://doi.org/10.58421/misro.v5i2.1032

implementing instant delivery also introduces significant operational challenges, particularly warehouse operations that must support high-speed order fulfillment under strict time constraints [4].

Marketplace ABC is one of the largest e-commerce platforms in Indonesia, operating more than 10 warehouses across multiple cities. Since April 2024, the company has introduced warehouse-based instant delivery services to meet customer expectations for same-day and near-immediate delivery. Unlike conventional delivery models, instant delivery orders are dispatched directly from warehouses to customers, bypassing intermediate hubs or temporary storage facilities [5]. To maintain delivery speed, motorcycle couriers are assigned a limited number of orders per trip. This operational structure places substantial pressure on warehouse processes, particularly the order pickup stage [6].

The order pickup process conducted by instant couriers represents the final operational step before orders leave the warehouse [7]. Although it is the last stage, this process plays a critical role in determining delivery timeliness, order accuracy, and overall customer satisfaction [8]. Inefficiencies at this stage can lead to delivery delays, increased operational costs due to mispicks or reprocessing, and a decline in customer trust toward instant delivery services. Consequently, improving the effectiveness and reliability of the order pickup process is essential to sustaining service quality and operational performance [9].

Two preceding activities strongly influence the performance of the instant courier pickup process: order sorting in the dispatch area and courier assignment. Order sorting determines the physical placement of orders within the warehouse, directly affecting picker travel distance and retrieval time. Courier assignment, on the other hand, determines which orders are grouped for delivery and the sequence in which they are collected, influencing both warehouse operations and downstream delivery routes [10]. A lack of alignment between these two processes can result in operational inefficiencies.

Observations at Warehouse A, one of Marketplace ABC's largest facilities, reveal that orders in the dispatch area are currently sorted manually by buyer name in alphabetical order. This method does not consider courier assignments, which are automatically generated by the system based on delivery route efficiency, with a maximum of three orders per courier. As a result, orders assigned to a single courier are often scattered across multiple racks, forcing pickers to move between locations and search for specific orders. Additionally, the physical order sequence on the racks does not match the courier arrival order, so orders requiring immediate pickup are not always readily accessible. These conditions increase pickup time and elevate the risk of picking errors.

Previous studies have explored various approaches to improving warehouse order-picking performance, including batch picking, workload balancing, and zone-cking systems [11]. Other research has demonstrated that zone picking combined with structured storage location assignment can significantly reduce picker travel distance and improve efficiency [12]. However, most existing studies focus on conventional warehouse operations or regular delivery systems and do not specifically address the operational characteristics of instant delivery, such as strict pickup time targets and limited order quantities per courier. This study addresses this research gap by proposing a zone-picking strategy specifically designed for warehouse-based instant delivery operations. The proposed approach integrates zone picking with delivery location-based clustering using the K-Means algorithm, enabling orders with similar geographic destinations to be grouped into the same picking zones. By aligning order sorting, physical placement, and courier assignment within these zones, the study aims to create a more synchronized and efficient pickup process.

The primary objective of this research is to design and evaluate an improved order pickup process for instant couriers at Warehouse A of Marketplace ABC by implementing zone picking based on delivery location clustering. The study seeks to assess the impact of this approach on reducing pickup time and improving pickup accuracy relative to established operational targets.

Table 1. Instant Order Volume and Pickup Process Performance in Warehouse A

Parameter	Unit	2024			2025		
		Apr	May	Jun	Jun	Jul	Aug
Average daily order volume	Orders	106	469	698	2,179	2,028	1,815
Maximum orders per assignment	Orders	2	2	2	3	3	3
Stack rate	%	36.0%	61.7%	63.4%	98.9%	99.0%	99.2%
Average delivery distance efficiency per order	%	15.6%	24.7%	25.1%	53.3%	51.9%	49.7%
Instant Courier Pickup Process Performance							
Pickup time	Minutes	2.8	3.1	3.8	4.9	6.3	6.7
Target	Minutes	3	3	3	3	3	3
Delta	Minutes	▼ 0.2	▲ 0.1	▲ 0.8	▲ 1.9	▲ 3.3	▲ 3.7
Pickup process inaccuracy per month	Orders	3	54	134	270	284	266
Target	Orders	0	0	0	0	0	0
Delta	Orders	3	54	134	270	284	266

Since the instant delivery service for warehouse orders was implemented in April 2024, the volume of instant orders from Warehouse A has continuously increased. In 2025, particularly from June onward, Marketplace ABC accelerated the adoption of this service through promotional programs, resulting in a significant surge in order volume. Although improvements in stack rate and maximum orders per courier assignment increased delivery distance efficiency, the absence of improvements in the courier pickup process led to longer pickup times and higher inaccuracy rates, exceeding the operational targets of a maximum 3-minute pickup time and 100% accuracy.

Inefficient and inaccurate pickup processes negatively affect buyers, couriers, and Marketplace ABC. Buyers experience dissatisfaction and reduced loyalty, couriers face reduced delivery capacity and income, while the marketplace risks declining user trust and financial losses from redelivery and product replacement. Previous approaches, such as batch picking and workload distribution, have not yielded optimal results (Deshpande & Kumar, 2020), underscoring the need for a more systematic, data-driven method.

Zone picking is proposed as an effective solution, as supported by [4] and [11]. In this study, zone picking is developed based on delivery location similarity using K-means clustering [13].

The study uses historical data from Warehouse A at Marketplace ABC in July 2025, covering both promotional and non-promotional conditions. The integration of K-Means-based zone picking is expected to reduce pickup time. Performance is evaluated against operational targets of a maximum 3-minute pickup time and 100% pickup accuracy.

The findings of this research are expected to contribute theoretically to the warehouse management and logistics literature by extending the application of clustering-based zone picking to the context of instant delivery. From a practical perspective, the results are expected to provide actionable insights for e-commerce operators seeking to enhance warehouse efficiency, improve instant-delivery performance, and strengthen customer satisfaction in high-speed fulfillment environments.

2. METHOD

Research Design

This research is an applied study with a quantitative approach. It aims to develop an algorithm-based solution to the pickup process for instant couriers in warehouses. The study uses historical data from Warehouse A, Marketplace ABC.

Overview of the Research Subject

E-commerce Company Profile

Marketplace ABC is one of the rapidly growing e-commerce platforms in Indonesia, headquartered in Singapore. It was founded in 2015 in Singapore and entered the Indonesian market in the same year. In addition to Indonesia, Marketplace ABC has expanded its operations to several Southeast Asian countries, including Malaysia, Thailand, Vietnam, and the Philippines.

Initially, Marketplace ABC operated as a C2C (consumer-to-consumer) platform that connected customers with one another. Over time, it adopted a hybrid model combining C2C and B2C (business-to-consumer). This transition began with the launch of Marketplace ABC Mall, a dedicated section of the platform that offers products from well-known brands through official stores with a 100% authenticity guarantee.

Since its launch in Indonesia, Marketplace ABC has offered various promotions, payment methods, and delivery options to attract more users. In addition, Marketplace ABC offers a service called “Managed by Marketplace ABC,” which helps sellers manage and sell their products on the platform. Products managed under this service are stored and processed in Marketplace ABC warehouses.

Warehouse Profile

This research is conducted at one of Marketplace ABC’s warehouses (Warehouse A), located in the Sunter area of North Jakarta, specifically at the Dunex Warehouse Complex. This warehouse is the largest storage facility owned by Marketplace ABC, with more than 10,000 products stored inside. The products mainly consist of daily necessities from various brands, including rice, instant seasonings, soap, baby diapers, and more.

Every day, this warehouse processes approximately 72,000 orders for delivery to various destinations, using several delivery methods, of which around 2% use instant delivery services.

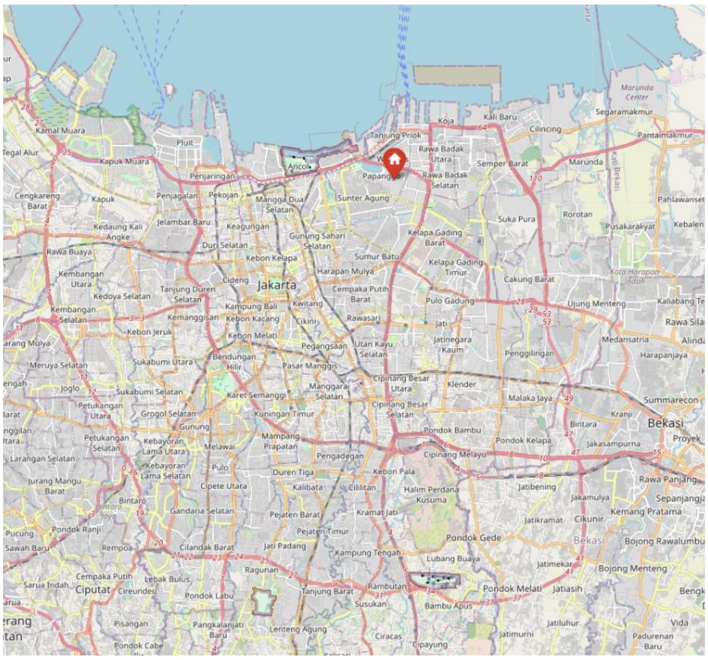

Figure 1. Location of Warehouse A

Research Data

The data used in this study is primary data in the form of historical orders obtained from the internal system of Warehouse A, Marketplace ABC, including:

a. Order ID,
b. Delivery location: Province, City/Regency, Subdistrict, Latitude, Longitude
c. Pickup request time

3. RESULTS AND DISCUSSION

3.1. Results

Formation of Picking Zones

After the order data has gone through the preprocessing stage, the next step is to form picking zones, which serve as the basis for improving the order pickup flow by instant couriers at Warehouse A. Picking zones are formed using the K-Means clustering approach, which groups delivery destinations into several zones based on geographic proximity.

The process of forming picking zones is carried out in two stages. First, determine the optimal number of zones using the Elbow method. Second, group delivery destinations based on the predetermined number of zones. Each stage will be implemented in Python, as shown in Figure 2.

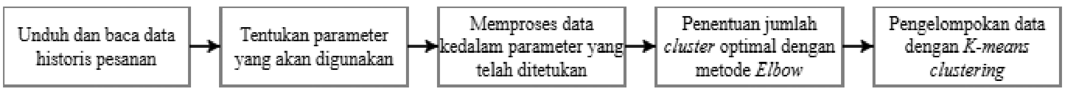

Figure 2. Formation of Picking Zones

Determination of the Number of Zone Picking

This study applies the zone-picking concept using the K-means clustering algorithm to group orders based on spatial proximity. Determining the appropriate number of clusters

(k) is essential: too few zones result in overly large coverage areas and inefficient delivery routes, while too many complicate order placement and may cause imbalance among zones.

The optimal number of clusters was determined using the Elbow method by analyzing the Sum of Squared Error (SSE). A smaller SSE indicates better clustering quality. The elbow point marks the stage at which additional clusters no longer provide significant improvement.

The Python-based analysis (Appendix B), shown in Figure 4.2, reveals a sharp decrease in SSE from k = 2 to k = 5, followed by a slower, insignificant decline. Therefore, the elbow point is identified at k = 5, and five zones are selected as the most optimal configuration, balancing clustering quality and operational feasibility in warehouse implementation.

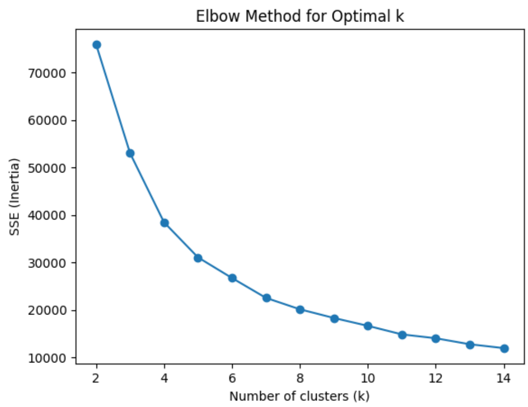

Figure 3. Elbow Method Results

Grouping Delivery Destinations into Picking Zones

After the optimal number of zones has been determined using the elbow method, the next step is to group orders into predetermined zones. This grouping is performed using the K-Means Clustering method, which calculates the distance of each order point to the center (centroid) and groups them into zones based on the closest distance. The centroid position is then updated based on the average coordinates of the orders within each zone, and this process is repeated iteratively until the centroid position remains unchanged. This ensures that orders that are geographically close and located in areas with high order density are concentrated within the same zone.

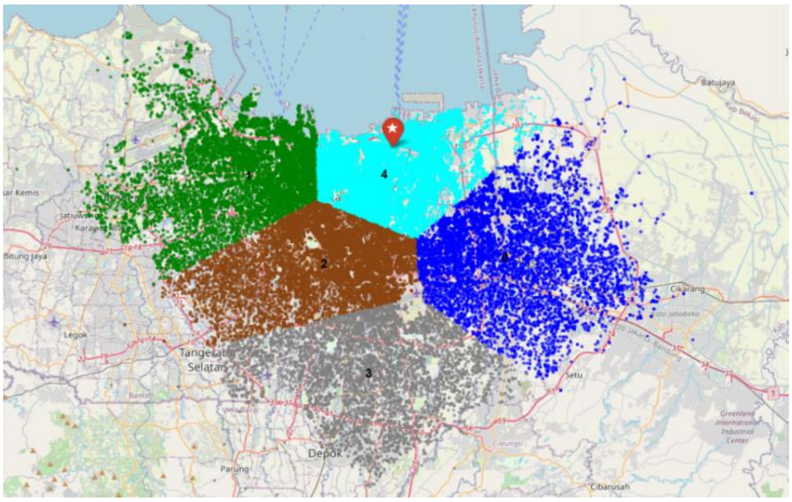

Figure 4. Order Grouping at Warehouse A Based on Picking Zones

The results of grouping with k = 5 zones (zones 0, 1, 2, 3, 4) using Python (APPENDIX B) are shown in Figure 4.3 (APPENDIX C), where each color represents a zone, hereinafter referred to as a picking zone, and a red asterisk indicates the warehouse location as the starting point for shipments. Picking Zone 0 – Dark Blue is dominated by orders destined for Bekasi City (±44%), Picking Zone 1 – Green primarily covers West Jakarta City (±56%), and Picking Zone 2 – Brown is dominated by shipments to South Jakarta City (±46%). Meanwhile, Picking Zone 3 – Gray receives most orders from East Jakarta, Depok City, and South Jakarta (±75%), while Picking Zone 4 – Light Blue receives most shipments to North Jakarta City (±57%).

Table 2. Results of Picking Zone Formation

Zone Picking	Centroid (Lat, Lon)	City/Regency	Average Orders per Day
0 – Dark Blue	(6.2267, 106.9808)	Bekasi City, East Jakarta City, Bekasi Regency, Bogor Regency, North Jakarta City, Central Jakarta City	273
1 – Green	(6.1537, 106.7470)	West Jakarta City, North Jakarta City, Tangerang City, Tangerang Regency, Central Jakarta City, South Tangerang City, Bogor Regency	418
2 – Brown	(6.2325, 106.8158)	South Jakarta City, East Jakarta City, Central Jakarta City, West Jakarta City, South Tangerang City, Tangerang City, Tangerang Regency	397
3 – Grey	(6.3317, 106.8564)	East Jakarta City, Depok City, South Jakarta City, Bekasi City, South Tangerang City, Bogor Regency, Tangerang Regency	178
4 – Light Blue	(6.1518, 106.8710)	North Jakarta City, Central Jakarta City, East Jakarta City, West Jakarta City, Bekasi Regency	722

From Table 2, it can be observed that the average daily orders per zone vary significantly. Zone picking 4 has the highest average with 722 orders per day, while zone picking 3 has the lowest with 178 orders per day. This variation indicates differences in workload across zones, allowing rack capacity to be adjusted based on each zone's historical order volume.

Redesign of the Instant Courier Pickup Process Flow in the Warehouse

After the zone picking structure was established, the next step was to redesign the instant courier pickup process flow in Warehouse A. As explained in Chapter 1 (Figure 1.1), the effectiveness of the pickup process is strongly influenced by two preceding stages: order sorting in the shipping area and courier assignment. Therefore, the improved design in this study begins with restructuring these two processes.

Order Sorting in the Shipping Area

Currently, order sorting in the shipping area is based on recipient names in alphabetical order. Although simple, this method has several weaknesses. Orders with nearby destinations may be placed on different racks, forcing pickers to move frequently. In addition, the workload among pickers is uneven because certain letters contain far more orders than others, increasing search difficulty and the risk of picking errors.

In the proposed design, sorting is no longer based on alphabetical order but on zone picking. Each zone is assigned to a specific rack labeled with a zone code (e.g., Z0, Z1, etc.), which is also printed on the order label. This eliminates the need for manual address checking. Orders are placed using a First In First Out (FIFO) mechanism, ensuring that earlier orders are picked first. This system improves order flow, reduces search time, balances workload, and minimizes the risk of errors during the pickup process.

Figure 5. Order Shelves in the Delivery Area

Furthermore, the shelves in the delivery area are positioned facing the order pickup table, where pickers hand orders to couriers for delivery. This arrangement aims to minimize the distance pickers travel when retrieving orders from shelves, resulting in a faster, more efficient process.

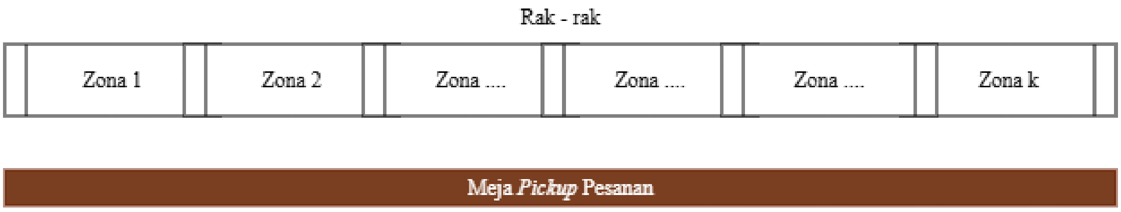

Figure 6. Delivery Area

Courier Assignment

In the current system, courier assignments are automatically generated, with a maximum of 3 orders per courier based on delivery route efficiency. Although effective for route optimization, this system creates inefficiencies in the warehouse because orders for one courier are often scattered across different racks due to alphabetical sorting. As a result, pickers must move between racks, increasing pickup time and the risk of errors. In addition, older orders are not always picked first.

In the proposed design, courier assignment remains automatic, but each courier is assigned to only one zone for picking. Couriers receive a zone code and barcode, which the picker scans upon arrival. Two main factors determine assignment:

1. Number of Orders in a Zone
   If the number of orders in a zone reaches the minimum threshold (M = 3 orders), the system immediately assigns a courier.
2. Service Time Limits
   a. Warehouse Operating Time Limit
      If operating hours end while a zone has fewer than three orders, a courier is still assigned to prevent order delays. Orders arriving after operating hours are processed the next day.
   b. Order Waiting Time Limit
      If an order remains in a zone for too long during operating hours, the system assigns a courier even if the minimum order threshold is not met. This ensures timely delivery and maintains customer satisfaction.

Order Pickup by Instant Couriers in the Warehouse

In the current process, couriers show the picker their assigned order list, and the picker then searches across multiple racks. Because the assignment does not account for the physical location of orders, the picker often moves between racks and searches within them, increasing pickup time and error risk.

In the proposed design, couriers present their zone code and barcode to the picker, who scans them. The picker then goes directly to the assigned zone rack and selects up to three orders using the FIFO principle, ensuring older orders are picked first. After scanning the airway bill (AWB), the orders are handed to the courier, who then scans each AWB to complete the pickup process.

This redesigned process reduces movement, shortens pickup time, and minimizes picking errors.

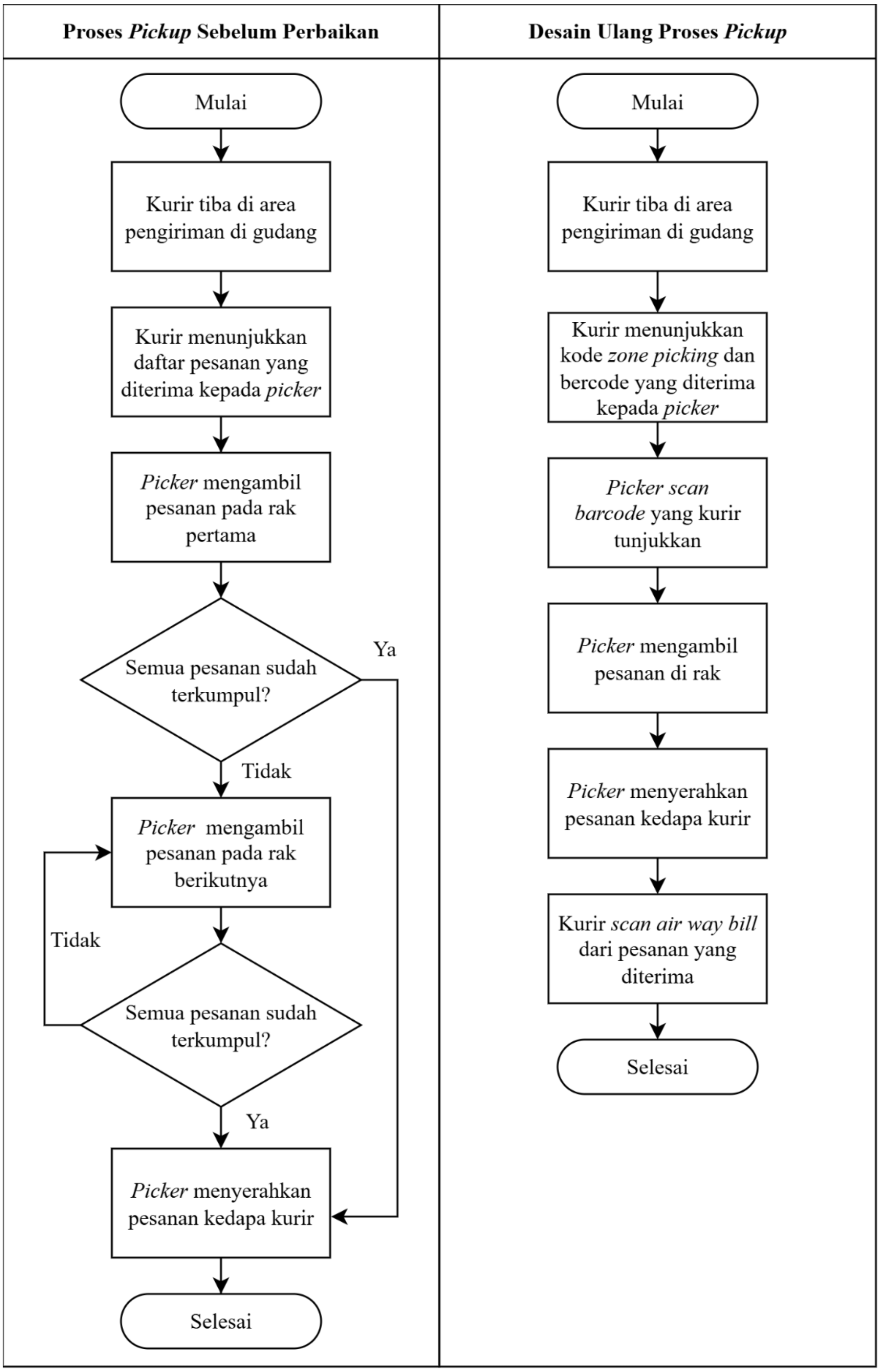

Figure 7. Order Pickup by Instant Couriers in the Warehouse

Overall, the differences in the warehouse order pickup process for instant couriers are shown in Table 3.

Table 3. Comparison of Order Pickup Processes

Process	Current Condition	Proposed Design
Order Sorting in Shipping Area	Based on the buyer's name, in alphabetical order, without considering order sequence.	Based on the zone picking generated by the clustering process. Orders are placed on racks starting from the side labeled "in" and shifted toward the side labeled "out."
Courier Assignment	An order list generated by the system based on route efficiency, consisting of a maximum of 3 orders.	The system determines the zone picking code and barcode based on the order conditions for each zone picking.
Order Picking by Picker	Follows the order list from the courier assignment, where orders may be located on different racks.	Taken only from one rack according to the zone picking code assigned to the courier. Orders are picked using FIFO with a maximum of 3 orders.

3.2. Discussion

Simulation & Results

The simulation in this study was conducted to determine changes in the order pickup process when instant couriers implemented zone picking in the delivery area. The simulation was conducted at Warehouse A and Marketplace ABC, focusing on the timing and accuracy of the pickup process.

Pickup Process Time and Accuracy

The time and accuracy of the pickup process were observed to determine changes in order pickup performance by instant couriers after the implementation of zone picking and the new pickup process flow at Warehouse A, Marketplace ABC. The new zone picking and pickup process flow began to be implemented in October 2025. Observations of pickup times were conducted by observing actual time data systematically recorded through barcode scanning activities by pickers and couriers during the pickup process in the delivery area, namely:

1. Pickup process start time, which is the time when the picker scans the barcode presented by the courier upon arrival at the delivery area.
2. Pickup process end time: the time when the courier scans the AWB for the orders received, indicating they have been picked up.

The difference between these two times is the pickup duration for each order. This data is taken directly from the system, ensuring all times are recorded objectively and accurately without manual intervention. Observations were made on approximately 2,247 instant orders, or 10% of instant orders from Warehouse A of Marketplace ABC, between October 110, 2025, using a random sample that accounted for variations in pickup process times.

Table 4. Average Order Pickup Processing Time After Implementing Zone Picking

Date	Number of Samples (Orders)	Average Pickup Time (Minutes)	Pickup Time Range (Minutes)	% Pickup Above Target
October 1, 2025	186	1.8	0.6 – 10.9	8.1%
October 2, 2025	282	1.8	0.4 – 6.0	8.9%
October 3, 2025	202	1.7	0.3 – 8.1	8.9%
October 4, 2025	170	1.6	0.7 – 8.4	4.1%
October 5, 2025	129	1.8	0.6 – 6.5	8.5%
October 6, 2025	188	1.8	0.6 – 9.8	9.0%
October 7, 2025	191	1.7	0.6 – 6.1	7.9%
October 8, 2025	190	1.6	0.6 – 3.8	4.7%
October 9, 2025	180	1.6	0.2 – 8.9	3.3%
October 10, 2025	529	1.8	0.4 – 9.2	9.1%
Average	2,247	1.7	0.2 – 10.9	7.6%

Based on the sample data observations, the average pickup processing time was 1.7 minutes per order. This indicates a significant reduction from 6.7 minutes to 1.7 minutes and meets the pickup target of 3 minutes or less. Although the overall target was achieved, approximately 7.6% of orders still exceeded the target time. This variation was mainly due to unstable mobile signal conditions during the scanning process, which delayed the recording of system time. The impact was more noticeable for orders scanned last, as each courier may handle up to three orders per pickup. Nevertheless, this issue did not significantly affect overall performance, as the average pickup time remained below the target.

In addition to time performance, pickup accuracy was also evaluated. In the improved process, each courier is restricted to picking orders from only one assigned zone and must scan the AWB for every order. This scanning process serves as an automatic validation mechanism. If a courier attempts to pick an order from an incorrect zone (which may occur due to sorting errors), the system automatically rejects it. Through this mechanism, pickup errors are eliminated, resulting in 100% pickup accuracy. This represents a substantial improvement compared to the previous condition, which recorded up to 200 errors per month, and fully meets the target of zero errors.

Overall, the implementation of zone picking combined with the redesigned pickup workflow has a positive impact on both pickup time and accuracy. The average pickup time is reduced because pickers only collect orders from a single zone without needing to search for specific orders, while pickup errors are completely prevented through AWB scanning validation [14]. Therefore, zone picking and the improved pickup process not only accelerate operations but also enhance operational accuracy and reduce human error in warehouse pickup activities.

Evaluation of Improvement Indicators

Based on the improvement success criteria, the following results were obtained to validate the research outcomes, as presented in Table 5.

Table 5. Examination of Improvement Indicator Results

No.	Improvement Success Indicator	Improvement Results
1	Establishment of a new pickup flow for instant courier order pickup using zone picking.	The new pickup process was successfully implemented, supported by improvements to order sorting and courier assignment that collectively enhanced the overall process.
2	Reduction of courier pickup time to approach or meet the warehouse operational target.	The average pickup time was successfully reduced from 6.7 minutes to 1.7 minutes. This result is also lower than the predetermined target of 3 minutes.
3	Improvement in pickup accuracy, indicated by a reduction in order picking errors.	Pickup accuracy increased to 100% by implementing a validation scanning process, ensuring couriers do not pick up orders from zones that do not match their assigned tasks.

From an operational perspective, the application of zone picking directly addressed the root causes of excessive pickup time identified in the initial condition. Prior to the improvement, orders assigned to a single courier were dispersed across multiple racks due to alphabetical sorting, requiring pickers to travel farther and conduct repeated searches. After implementing zone-based sorting, orders were consolidated within designated racks by their assigned zones, enabling pickers to retrieve multiple orders from a single location. This reduction in picker travel distance aligns with previous studies that emphasize that travel time accounts for the largest share of order-picking time and is a critical determinant of warehouse efficiency [15].

The redesign of the courier assignment mechanism further reinforced the effectiveness of zone picking. Although courier assignment continued to be generated automatically by the system, restricting each courier to a single picking zone ensured consistency between order grouping and physical placement [16]. The use of operational constraints, namely minimum order thresholds, waiting time limits, and warehouse operating hours, allowed the system to remain flexible while preventing excessive order delays. This approach reflects the principles of synchronized zone picking systems, in which coordination between picking and dispatch decisions is essential to avoid bottlenecks and imbalances [17].

The simulation results provide strong empirical evidence of performance improvement. The average pickup time decreased from approximately 6.7 minutes to 1.7 minutes, representing a reduction of nearly 75% and exceeding the operational target of 3 minutes or less. This finding supports earlier research indicating that zone picking can significantly shorten picking time when supported by appropriate storage assignment and workflow design [18], [19]. In the context of instant delivery, where speed is a critical service attribute, such reductions have a direct and meaningful impact on delivery timeliness and courier productivity.

In addition to time efficiency, pickup accuracy reached 100% following implementation. The integration of barcode scanning for zone codes and airway bills (AWB) served as an automated validation mechanism, preventing couriers from collecting orders from the wrong zones. This result highlights the importance of combining physical process redesign with information system controls. Unlike manual checking, which is prone to human error under time pressure, system-based validation ensures consistent accuracy [20]. This outcome extends prior findings on error reduction in order picking by demonstrating that accuracy improvements can be fully achieved when zoning strategies are coupled with real-time digital verification [21].

Despite the overall success, a small proportion of orders (approximately 7.6%) still exceeded the pickup time target. However, these deviations were primarily attributed to external factors, such as unstable mobile network connectivity during barcode scanning, rather than to process inefficiencies. Importantly, these delays did not compromise overall system performance, as the average pickup time remained well below the operational threshold. This observation suggests that further improvements may be achieved through infrastructure enhancements rather than additional process redesign [22].

Compared to previous studies, this research offers a novel contribution by applying clustering-based zone picking specifically to warehouse-based instant delivery operations. While earlier research largely focused on conventional order picking or regular distribution systems, this study demonstrates that zone picking remains highly effective even under the strict time constraints and limited order capacities characteristic of instant delivery. The integration of spatial clustering with operational rules for courier assignment provides a practical, scalable solution for high-speed fulfillment environments.

4. CONCLUSION

Conclusion

This study concludes that aligning warehouse order pickup processes with delivery-location-based zoning provides a robust operational framework for instant delivery services. By structuring order handling around spatial proximity rather than alphabetical or arbitrary criteria, the pickup process becomes more coherent, predictable, and operationally synchronized. The findings indicate that zone-oriented warehouse design is particularly suitable for environments characterized by high time pressure and limited delivery capacity per courier, such as instant delivery systems.

From a managerial and operational perspective, this research suggests that warehouse inefficiencies in instant delivery are not solely driven by high order volumes but are largely rooted in misaligned processes for order sorting, physical placement, and courier assignment [23]. The proposed zone-based approach demonstrates that integrating data-driven clustering techniques with operational rules can support faster decision-making, reduce unnecessary movement within warehouses, and enhance process reliability. These implications are especially relevant for e-commerce operators seeking scalable solutions without major infrastructure expansion [24].

The scope of this research is subject to several boundaries. First, the study is based on a single warehouse case, which may limit the generalizability of the findings to warehouses with different layouts, order profiles, or delivery characteristics [25]. Second, the analysis focuses on pickup time and accuracy as primary performance indicators, without explicitly examining labor costs, system investment costs, or long-term financial impacts. Third, the clustering model relies on historical order distribution within a specific time period, which may not fully capture seasonal or long-term demand fluctuations.

Future research is encouraged to extend this approach by testing alternative clustering methods, varying the number and configuration of picking zones, or incorporating dynamic zoning that adapts to real-time demand patterns. Further studies may also integrate workforce optimization, cost-benefit analysis, and peak-demand simulation to evaluate the economic sustainability of zone-based pickup systems. Additionally, comparative studies across multiple warehouses or platforms would strengthen the external validity of the findings.

Beyond its academic contribution, this research offers practical value to the general public by supporting faster, more reliable instant delivery services, thereby directly enhancing the customer experience in e-commerce transactions. Improved pickup efficiency also benefits couriers by creating more predictable workloads and delivery schedules, while marketplaces gain increased operational resilience and customer trust. Overall, this study contributes to advancing data-driven logistics practices that support sustainable and responsive urban delivery systems.

Recommendations

1. Future studies should examine different numbers of zone-picking and order groups using larger datasets and consider changes in delivery distribution patterns.
2. Further analysis is needed to determine the optimal number of warehouse staff for the pickup process, accounting for order volume, effective working hours, and workload balance.
3. A detailed cost analysis is recommended to evaluate the financial impact of zone picking implementation on warehouse operations, including return on investment (ROI), especially if applied to other warehouses.

ACKNOWLEDGEMENTS

The author sincerely thanks all parties who contributed to the completion of this study, especially the management and staff of ABC Marketplace Warehouse A for their permission, data, and valuable insights. Appreciation is also extended to academic supervisors and colleagues for their guidance, constructive feedback, and continuous support throughout the research process. Finally, the author is deeply grateful to family and friends for their motivation and encouragement, and hopes that this study will contribute meaningfully to warehouse logistics optimization and future research.

REFERENCES

[1] Y. Xia, Y. Hu, C. Wu, L. Yang, And M. Lei, "Challenges Of Online Learning Amid The Covid-19: College Students' Perspective," *Front. Psychol.*, Vol. 13, Dec. 2022, Doi: 10.3389/Fpsyg.2022.1037311.

[2] B. Kusuma Wijaya And W. Eny Mariani, "Dampak Pandemi Covid-19 Pada Sektor Perhotelan Di Bali," *Warmadewa Management And Business Journal (Wmbj) Februari 2021© All Right Reserved*, Vol. 3, No. 1, Pp. 49–59, 2021, [Online]. Available: Www.Worldometer.Info

[3] E. Y. Nasution, P. Hariani, L. S. Hasibuan, And W. Pradita, "Perkembangan Transaksi Bisnis E-Commerce Terhadap Pertumbuhan Ekonomi Di Indonesia," *Jesya*, Vol. 3, No. 2, Pp. 506–519, Jun. 2020, Doi: 10.36778/Jesya.V3i2.227.

[4] R.-Q. Zhang, M. Wang, And X. Pan, "New Model Of The Storage Location Assignment Problem Considering Demand Correlation Pattern," *Comput. Ind. Eng.*, Vol. 129, Pp. 210–219, Mar. 2019, Doi: 10.1016/J.Cie.2019.01.027.

[5] S. Vanheusden, T. Van Gils, A. Caris, K. Ramaekers, And K. Braekers, "Operational Workload Balancing In Manual Order Picking," *Comput. Ind. Eng.*, Vol. 141, P. 106269, Mar. 2020, Doi: 10.1016/J.Cie.2020.106269.

[6] W. Chen, Y. Zhang, And Y. Zhou, "Integrated Scheduling Of Zone Picking And Vehicle Routing Problem With Time Windows In The Front Warehouse Mode," *Comput. Ind. Eng.*, Vol. 163, P. 107823, Jan. 2022, Doi: 10.1016/J.Cie.2021.107823.

[7] Y. Setyowati, S. Priambudi, And D. Dewanto, "Supervision Of The Development Of Higher-Order Thinking Skills (Hots)-Based Assessment Of Learning In Wijaya Putra School," *Mattawang: Jurnal Pengabdian Masyarakat*, Vol. 4, No. 4, Pp. 367–376, Dec. 2023, Doi: 10.35877/454ri.Mattawang2240.

[8] A. Baskar And M. Anthony Xavior, "A Facility Location Model For Marine Applications," *Mater. Today Proc.*, Vol. 46, Pp. 8143–8147, 2021, Doi: 10.1016/J.Matpr.2021.03.107.

[9] A. Anđelković And M. Radosavljević, "Improving Order-Picking Process Through Implementation Of Warehouse Management System," *Strategic Management*, Vol. 23, No. 2, Pp. 3–10, 2018, Doi: 10.5937/Straman1801003a.

[10] J. P. Van Der Gaast, R. B. M. De Koster, I. J. B. F. Adan, And J. A. C. Resing, "Capacity Analysis Of Sequential Zone Picking Systems," *Oper. Res.*, Vol. 68, No. 1, Pp. 161–179, Jan. 2020, Doi: 10.1287/Opre.2019.1885.

[11] S. K. Schaumann, F. M. Bergmann, S. M. Wagner, And M. Winkenbach, "Route Efficiency Implications Of Time Windows And Vehicle Capacities In First- And Last-Mile Logistics," *Eur. J. Oper. Res.*, Vol. 311, No. 1, Pp. 88–111, Nov. 2023, Doi: 10.1016/J.Ejor.2023.04.018.

[12] S. Saylam, M. Çelik, And H. Süral, "The Min–Max Order Picking Problem In Synchronised Dynamic Zone-Picking Systems," *Int. J. Prod. Res.*, Vol. 61, No. 7, Pp. 2086–2104, Apr. 2023, Doi: 10.1080/00207543.2022.2058433.

[13] M. A. Rahman, M. A. Basheer, Z. Khalid, M. Tahir, And M. Uppal, "Logistics Hub Location Optimization: A K-Means And P-Median Model Hybrid Approach Using Road Network Distances," *Transportation Research Procedia*, Vol. 84, Pp. 219–226, 2025, Doi: 10.1016/J.Trpro.2025.03.066.

[14] T.-A. Chiang, Z.-H. Che, And C.-W. Hung, "A K-Means Clustering And The Prim's Minimum Spanning Tree-Based Optimal Picking-List Consolidation And Assignment Methodology For Achieving The Sustainable Warehouse Operations," *Sustainability*, Vol. 15, No. 4, P. 3544, Feb. 2023, Doi: 10.3390/Su15043544.

[15] J. Park, C. Park, And S. Hong, "Gaussian Process-Based Storage Location Assignments With Risk Assessments For Progressive Zone Picking Systems," *Comput. Ind. Eng.*, Vol. 185, P. 109700, Nov. 2023, Doi: 10.1016/J.Cie.2023.109700.

[16] A. Deshpande And M. R. Kumar, "An Optimized Cluster Based Warehouse Pickup Process," In *2020 Second International Conference On Inventive Research In Computing Applications (Icirca)*, Ieee, Jul. 2020, Pp. 462–467. Doi: 10.1109/Icirca48905.2020.9183220.

[17] F. Liu And Y. Deng, "Determine The Number Of Unknown Targets In Open World Based On Elbow Method," *Ieee Transactions On Fuzzy Systems*, Vol. 29, No. 5, Pp. 986–995, May 2021, Doi: 10.1109/Tfuzz.2020.2966182.

[18] J. Kim And S. Hong, "A Dynamic Storage Location Assignment Model For A Progressive Bypass Zone Picking System With An S/R Crane," *Journal Of The Operational Research Society*, Vol. 73, No. 5, Pp. 1155–1166, May 2022, Doi: 10.1080/01605682.2021.1892462.

[19] H. Kalkha, A. Khiat, A. Bahnasse, And H. Ouajji, "Enhancing Warehouse Efficiency With Time Series Clustering: A Hybrid Storage Location Assignment Strategy," *Ieee Access*, Vol. 12, Pp. 52110–52126, 2024, Doi: 10.1109/Access.2024.3386887.

[20] T. Gaon, Y. Gabay, And M. Weiss Cohen, "Optimizing Electric Vehicle Routing Efficiency Using K-Means Clustering And Genetic Algorithms," *Future Internet*, Vol. 17, No. 3, P. 97, Feb. 2025, Doi: 10.3390/Fi17030097.

[21] M. Haonan, Y. C. He, M. Huang, Y. Wen, Y. Cheng, And Y. Jin, "Application Of K-Means Clustering Algorithms In Optimizing Logistics Distribution Routes," In *2019 6th International Conference On Systems And Informatics (Icsai)*, Ieee, Nov. 2019, Pp. 1466–1470. Doi: 10.1109/Icsai48974.2019.9010223.

[22] J. Habazin, A. Glasnović, And I. Bajor, "Order Picking Process In Warehouse: Case Study Of Dairy Industry In Croatia," *Promet - Traffic&Transportation*, Vol. 29, No. 1, Pp. 57–65, Feb. 2017, Doi: 10.7307/Ptt.V29i1.2106.

[23] S. Tinggi Ilmu Kesehatan Muhammadiyah Klaten *Et Al.*, "Covid 19 (Studi Kasus Dikota Pekalongan)."

[24] F. Sudirjo, T. Purwati, Y. Unggul Budiman, And M. Manuhutu, "Analisis Dampak Strategi Pemasaran Digital Dalam Meningkatkan Loyalitas Pelanggan: Perspektif Industri E-Commerce," *Jurnal Pendidikan Tambusa*, Vol. 7, Pp. 7524–7532, 2023.

[25] A. Felix, S. Felina, And C. Claudia Natalie, "Memahami Kepuasan Pelanggan : Mengeksplorasi Customer Experience Dengan Pendekatan Observasi Online," *Economics And Digital Business Review*, Vol. 5, 2024.